EXPERIMENT 3

A) EXPERIMENT NAME: Tensile Test

B) THE AIM OF THE EXPERIMENT: Tension test is carried out; to obtain the stress-strain diagram, to determine the tensile properties and to get valuable information about the mechanical behavior and the engineering performance of the material.

C) EXPERIMENTAL SETUP AND APPARATUS

The testing equipment is Shimadzu Autograph AG-IS 100 computerized servo hydraulic universal testing machine with non-shift wedge type grips (Figure 1 and Figure 2). The tensile tests are performed according to DIN EN ISO 6892-1 at room temperature (23±1ºC) by 100kN of load cell. During the tests the load (force) and displacement (extension) data were processed by Trapezium 2 materials testing operation software.

Figure 1. A photograph of a tensile machine, Shimadzu Autograph

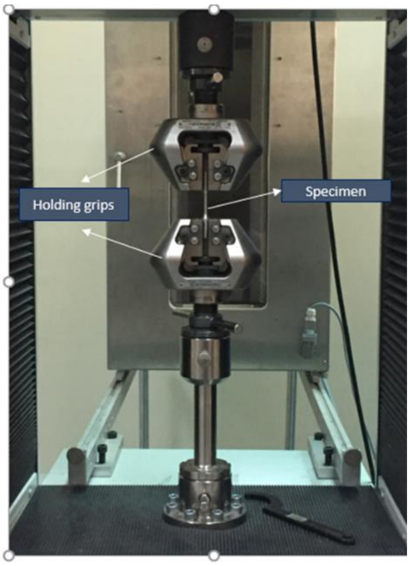

Figure 2. The holding grips and tensile specimen

D) THEORY

Stress, in the metric system, is usually measured in N/m^2 or Pa, such that 1 N/m^2 = 1 Pa. From the experiment, the value of stress is calculated by dividing the amount of force (P) applied by the machine in the axial direction by its cross-sectional area (A_o), which is measured prior to running the experiment. Mathematically, it is expressed in Equation 1. The strain values, which have no units, can be calculated using Equation 2, where L is the instantaneous length of the specimen and L_0 is the initial length (Figure 3)

$$\sigma = \frac{P}{A} \quad (1)$$

$$\varepsilon = \frac{L - L_0}{L_0} \quad (2)$$

$$A = \frac{\Delta L}{L_o} \quad (3)$$

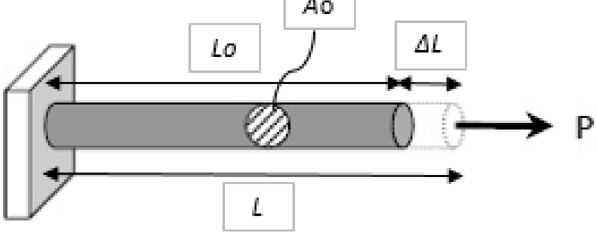

Figure 3. Elongation of a bar under tension

A typical stress-strain diagram would look like Figure 4. It is an ideal example of a stress-strain curve. In reality, not all stress-strain curves perfectly resemble the one shown in Figure 4. This stress-strain curve is typical for ductile metallic elements. Another thing to take note is that Figure 4 shows an "engineering stress-strain" curve. When a material reaches its ultimate stress strength of the stress-strain curve, its cross-sectional area reduces dramatically, a term known as necking.

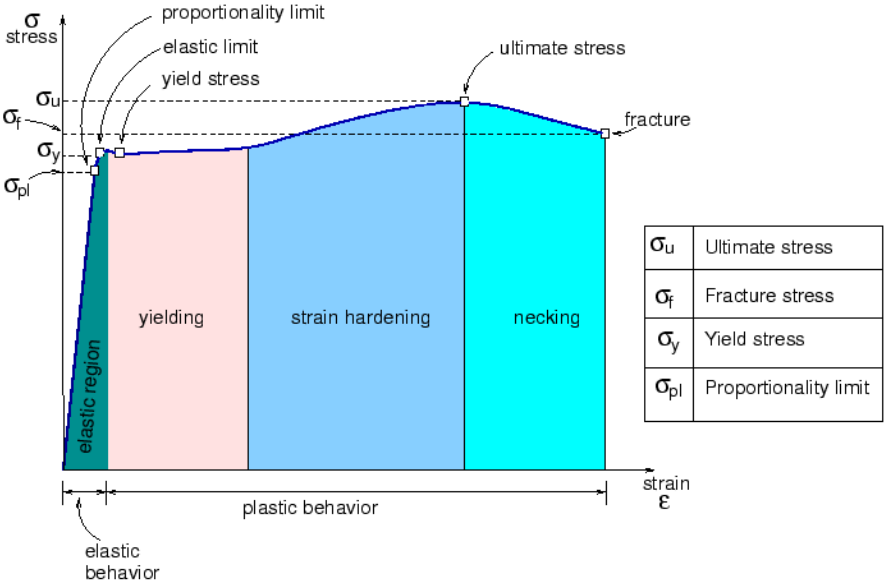

Figure 4a. A typical stress-strain diagram

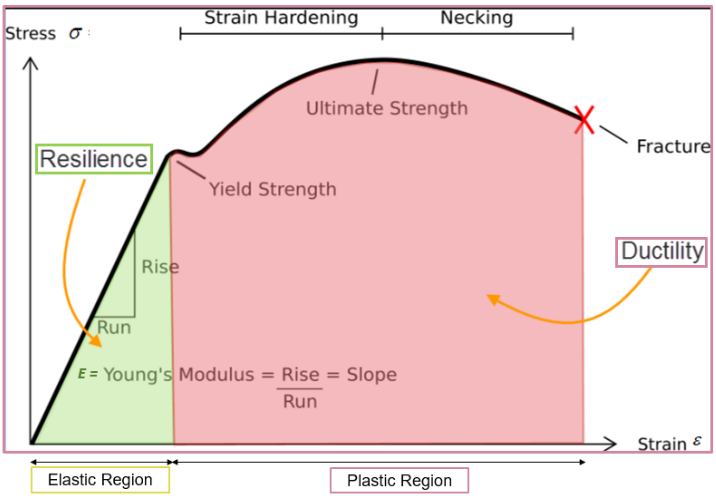

Figure 4b. A typical stress-strain diagram

When the computer software plots the stress-strain curve, it assumes that the cross sectional area stays constant throughout the experiment, even during necking, therefore causing the curve to slope down. The "true" stress-strain curve could be constructed directly by installing a "gauge," which measures the change in the cross sectional area of the specimen throughout the experiment.

Figure 4 also shows that a stress-strain curve is divided into four regions: elastic, yielding, strain hardening (commonly occurs in metallic materials), and necking. The area under the curve represents the amount of energy needed to accomplish each of these "events." The total area under the curve (up to the point of fracture) is also known as the modulus of toughness. This represents the amount of energy needed to break the sample, which could be compared to the impact energy of the sample, determined from impact tests. The area under the linear region of the curve is known as the modulus of resilience. This represents the minimum amount of energy needed to deform the sample.

The linear region of the curve of Figure 4 which is called as elastic region where a material behaves elastically. The material will return to its original shape when a force is released while the material is in its elastic region. The slope of the curve, which can be calculated using Equation 5 known as Hook's Law, is a constant and is an intrinsic property of a material known as the elastic modulus (modulus of elasticity or Young's modulus), E. In metric units, it is usually expressed in Pascal (Pa).

$$E = \frac{\sigma}{\varepsilon} \tag{4}$$

The part of the stress-strain diagram after the yielding point is called as plastic region. At the yielding point, the plastic deformation starts. Plastic deformation is permanent. At the maximum point of the stress-strain diagram (σ_u or UTS), necking starts.

Ultimate tensile strength (UTS) is the maximum stress that the material can support.

$$UTS = \sigma_u = \frac{P_{max}}{A_o} \tag{5}$$

Yield strength is the stress level at which plastic deformation starts. The beginning of first plastic deformation is called yielding.

$$\sigma_y = \frac{P_y}{A_o} \tag{6}$$

Poisson ratio ($\boldsymbol{v}$) is the lateral contraction per unit breadth divided by the longitudinal extension per unit length (Figure 5). It can be calculated by Equation 7.

$$v = -\frac{\varepsilon_{\text{lateral}}}{\varepsilon_{\text{longitudinal}}} \tag{7}$$

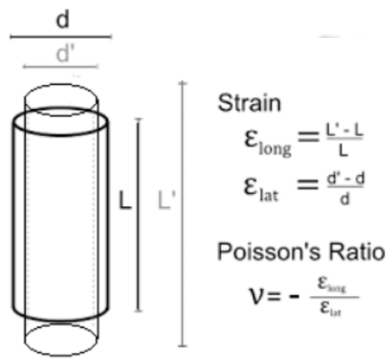

Figure 5. A typical stress-strain diagram

Percentage elongation is the highest plastic elongation percentage value. If the sample subjected to the tensile test is broken, the final length (L) can be measured after fitting together the broken parts of the sample. Then percentage elongation is calculated by Equation 8

$$\% \text{ Elongation} = \frac{L - L_o}{L_o} \text{ x } 100 \qquad (8)$$

Percent reduction of area is determined by measuring the minimum diameter of the broken test specimen after the two pieces are fitted together and the difference is expressed as a percentage of the original cross sectional area prior to the test (Equation 9)

$$\% \text{ Reduction of area} = \frac{Ao - A}{Ao} \text{ x } 100 \qquad (9)$$

A_o and A are initial cross sectional area of the sample and final area of sample respectively. To find final area (A), volume constancy principle ($V_o = V$) can be used as follows.

$A_o\ L_o = A\ L$

Then

$$A = \frac{A_o\ L_o}{L} \qquad (10)$$

Resilience is the ability of a material to absorb energy under elastic deformation and to recover this energy at removal of load. In the stress–strain curve, the area under the material's elastic region indicates that material's resilience. Area of the elastic region is given by Equation 11

$$U_r = \frac{\sigma_y\ \varepsilon_y}{2} \qquad (11)$$

Ductility is ability of a material to undergo permanent deformation through elongation (reduction in cross-sectional area)

$$U_t = \int_0^{\varepsilon} \sigma \ d\varepsilon \qquad (12)$$

E) EXPERIMENTAL PROCEDURE:

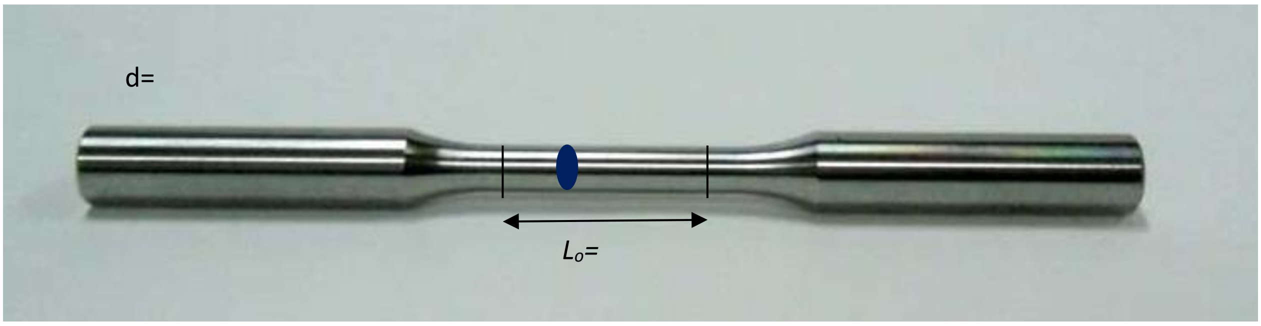

Figure 6. Tensile test specimen

1. Measure the dimensions of the specimen (L_o, d) by using vernier caliper to measure the diameter and the gage length (Figure 6)

2. Mark the gage length at three different portions on the specimen, covering effective length of a specimen. (This is required so that necked portion will remain between any two points of gage length on the specimen.)

3. Grip the specimen in the fixed head of the machine.

4. Fix the extensometer within the gauge length marked on the specimen. Set the dial of the extensometer to zero.

5. To read load applied, set the dial of the tensile testing machine to zero.

6. Select suitable increments for loading so that corresponding elongation can be measured from dial gauge.

7. Keep the speed of the tensile testing machine constant. Record the yield point, maximum load point, the point of breaking of specimen.

8. Remove the specimen from machine and study the fracture observes type of fracture.

9. Measure the final dimensions of tensile specimen. Fit the broken parts together and measure the final length then calculate the final area.

F) ASSIGNMENTS

1. Calculate the stresses and the strains for each interval of loading.
2. Draw the engineering stress-strain diagram and show approximate value of the yield stress, ultimate tensile stress and fracture stress on the curve.
3. Draw the true stress-strain (MPa-mm/mm) diagram.
4. Discuss what is the difference between engineering and true stress-strain curve?
5. Calculate the lateral and longitudinal strain then find the Poison’s ratio.
6. Calculate the modulus of elasticity.
7. Calculate the percentage elongation and the percentage reduction in area.
8. Find the resilience and ductility under the area of stress-strain curve according to engineering stress-strain diagram.