# TENSION TEST

## 1. OBJECT

The purpose of this experiment is to understand the uniaxial tensile testing and provide knowledge of the application of the tensile test machine.

## 2. INTRODUCTION

Tensile testing is one of the simplest and most widely used mechanical tests. By measuring the force required to elongate a specimen to breaking point, material properties can be determined that will allow designers and quality managers to predict how materials and products will behave in application.

## 3. THEORY

Tensile tests are performed for several reasons. The results of tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared. Finally, tensile properties often are used to predict the behavior of a material under forms of loading other than uniaxial tension.

The strength of a material often is the primary concern. The strength of interest may be measured in terms of either the stress necessary to cause appreciable plastic deformation or the maximum stress that the material can withstand. These measures of strength are used, with appropriate caution (in the form of safety factors), in engineering design. Also of interest is the material's ductility, which is a measure of how much it can be deformed before it fractures. Rarely is ductility incorporated directly in design; rather, it is included in material specifications to ensure quality and toughness. Low ductility in a tensile test often is accompanied by low resistance to fracture under other forms of loading. Elastic properties also may be of interest, but special techniques must be used to measure these properties during tensile testing, and more accurate measurements can be made by ultrasonic techniques.

**Engineering Stress** is the ratio of applied force $P$ and and cross section or force per area.

$$\sigma = \frac{P}{A_0}$$

$\boldsymbol{\sigma}$ is engineering stress

$P$ is the external axial tensile load

$A_0$ is the original cross-sectional area

There are three types of stresses an seen in Fig. 1.

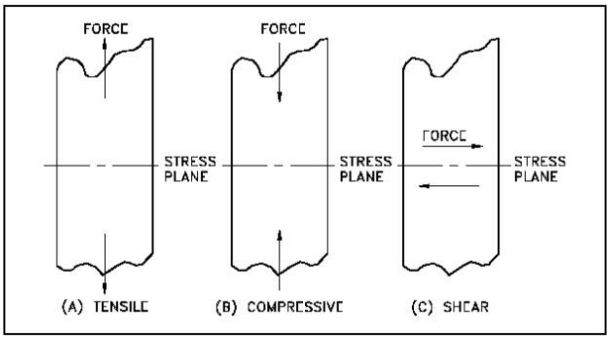


**Figure 1. Types of the stresses**

**Engineering Strain** is defined as extension per unit length.

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L_f - L_0}{L_0}$$

$\varepsilon$ is the engineering strain

$L_0$ is the original length of the specimen

$L_f$ is the final length of the specimen

An example of the engineering stress-strain curve for a typical engineering alloy is shown in Figure 2. From it some very important properties can be determined. The elastic modulus, the yield strength, the ultimate tensile strength, and the fracture strain are all clearly exhibited in an accurately constructed stress strain curve.

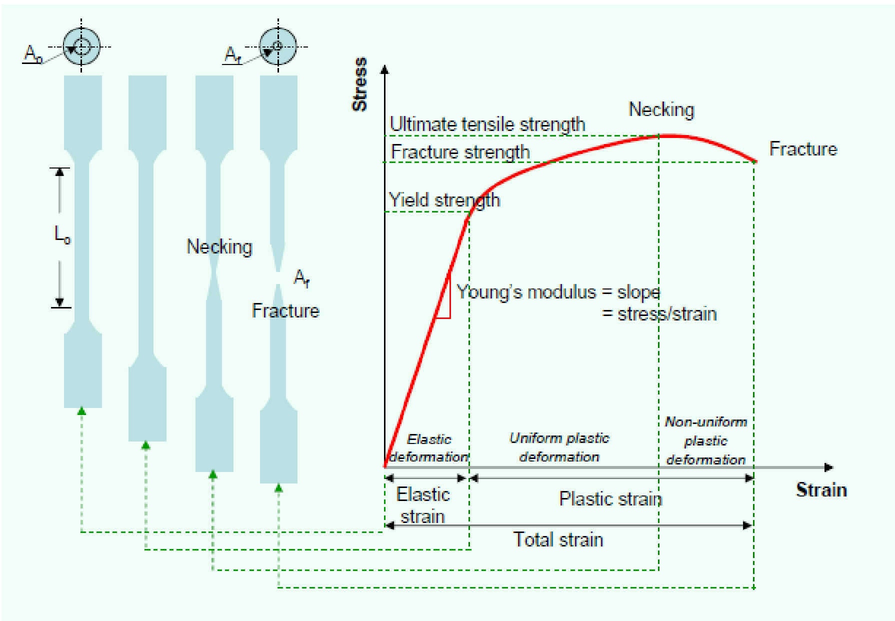


**Figure 2. Stress-strain curve**

**True stress** is the stress determined by the instantaneous load acting on the instantaneous cross-sectional area (Fig. 3).

$\sigma_T = P/A_i$

**True strain** is the rate of instantaneous increase in the instantaneous gauge length (Fig.3).

$\varepsilon_T = \ln (l_i/l_o)$

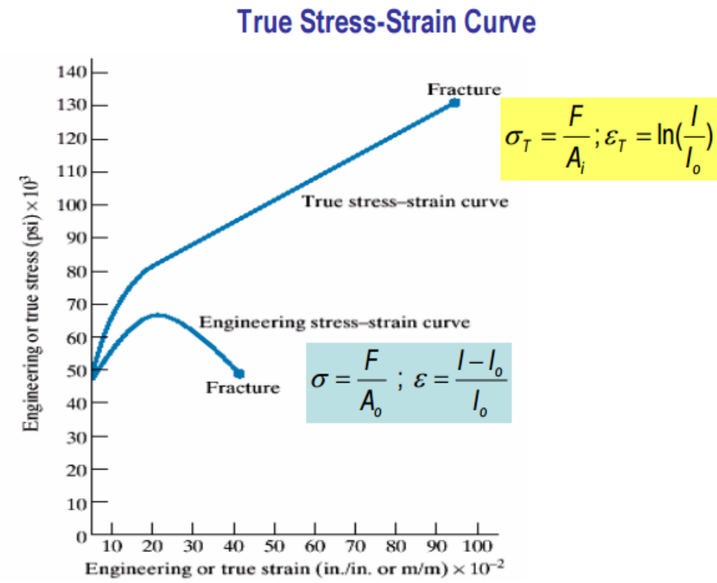


**Figure 3. True Stress-strain curve**

**True stress-engineering stress relation:**

$\sigma_T = \sigma(\varepsilon + 1)$

**True strain-engineering strain relation:**

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

**Elastic region:** The part of the stress-strain curve up to the yielding point. Elastic deformation is recoverable. In the elastic region stress and strain are related to each other linearly. *E* is Modulus of Elasticity or Young Modulus which is specific for each type of material.

*Hooke's Law*: $\sigma = E\varepsilon$

**Plastic region:** The part of the stress-strain diagram after the yielding point. At the yielding point, the plastic deformation starts. Plastic deformation is permanent. At the maximum point of the stress-strain diagram ($\sigma_{UTS}$), necking starts.

**Ultimate Tensile Strength, $\sigma_{UTS}$** is the maximum strength that material can withstand.

$$\sigma_{UTS} = \frac{Pmax}{A_0}$$

**Yield Strength, $\boldsymbol{\sigma_Y}$** is the stress level at which plastic deformation initiates. The beginning of first plastic deformation is called yielding. 0,2% off-set method is a commonly used method to determine the yield stength. $\sigma_Y$ (0.2%) is found by drawing a parallel line to the elastic region and the point at which this line intersects with the stress-strain curve is set as the yielding point (Fig 4).

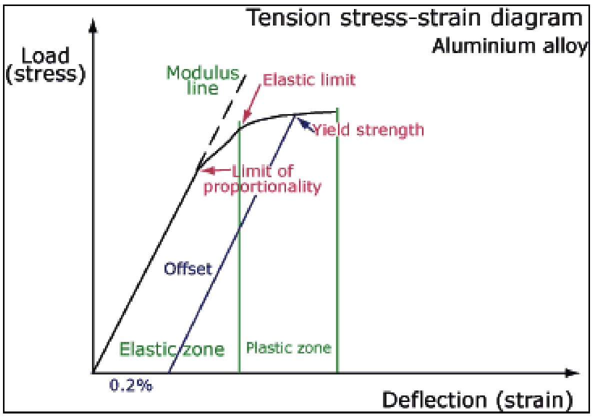


**Figure 4. Stress-strain curve**

**Fracture Strength**, $\boldsymbol{\sigma_F}$**:** After necking, plastic deformation is not uniform and the stress decreases accordingly until fracture.

$$\sigma_F = \frac{Pf}{A_0}$$

**Toughness:** The ability of a metal to deform plastically and to absorb energy in the process before fracture is termed toughness. The emphasis of this definition should be placed on the ability to absorb energy before fracture. Toughness of the different materials is seen in the Fig. 5.

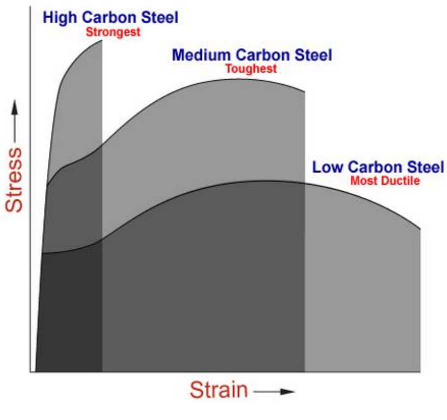


**Fig. 5. Toughness of the materials**

**Ductility** is a measure of how much something deforms plastically before fracture, but just because a material is ductile does not make it tough. The key to toughness is a good combination of strength and ductility. A material with high strength and high ductility will have more toughness than a material with low strength and high ductility. Ductility can be described with the percent elongation or percent reduction in area.

$\% \, Elongation = \frac{L_f - L_0}{L_0} 100$ (percent elongation)

$\% RA = \frac{A_0 - A_f}{A_0} 100$ (percent reduction in area)

**Resilience:** By considering the area under the stress-strain curve in the elastic region, this area represents the stored elastic energy or resilience.

## 4. EXPERIMENTS TO BE PERFORMED

The test unit will be introduced in the laboratory before the experiment by the relevant assistant.

**Tensile Specimens:** Consider the typical tensile specimen shown in Fig. 6. It has enlarged ends or shoulders for gripping. The important part of the specimen is the gage section. The cross-sectional area of the gage section is reduced relative to that of the remainder of the specimen so that deformation and failure will be localized in this region. The gage length is the region over which measurements are made and is centered within the reduced section. The distances between the ends of the gage section and the shoulders should be great enough so that the larger ends do not constrain deformation within the gage section, and the gage length should be great relative to its diameter. Otherwise, the stress state will be more complex than simple tension.

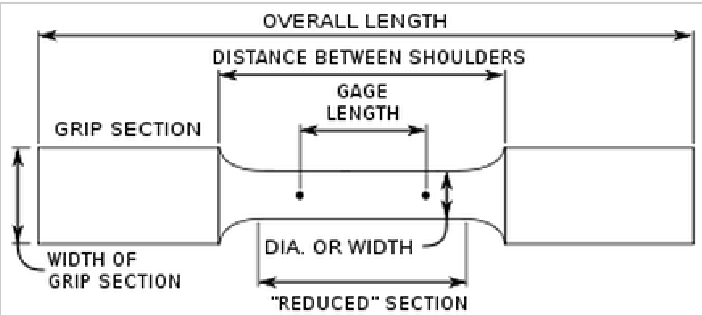


**Figure 6. Test specimen**

**Test machine:** The most common testing machines are universal testers, which test materials in tension, compression, or bending. Their primary function is to create the stress-strain curve. Testing machines are either electromechanical or hydraulic. The principal difference is the method by which the load is applied. Electromechanical machines are based on a variable-speed electric motor; a gear reduction system; and one, two, or four screws that move the crosshead up or down. This motion loads the specimen in tension or compression. Crosshead speeds can be changed by changing the speed of the motor (Fig.7)

**Figure 7. Tension test equipment**

**Experimental steps:** Specimen is machined in the desired orientation and according to the standarts. Aluminum, steel or composite materials can be used as the specimen material mostly. Magnitude of the load is chosen with respect to the tensile strength of the material. Specimen is fit to the test machine. Maximum load is recorded during testing. After fracture of the material, final gage length and diameter is measured. Diameter should be measured from the neck.

The necessary data for calculations will be recorded to the Table 1 given below.

**Table 1. Data which is entered into the system**

| **Measurement No:** | **Steel** |
|---|---|
| Force, $P$ [N] | |
| Specimen dimension, $d_0$ [mm] | |
| Length, $l_0$ [mm] | |
| Test speed, mm/dk | |

**4.1 Results**

**Calculate** the values given in Table 2.

**Table 2. Results obtained from test data**

| **Details** | **Steel** |
|---|---|
| *Maximum force, $P_{max}$ [N] | |
| *Final length, $l_f$ [mm] | |
| *Final Diameter, $d_f$ [mm] | |
| Final Cross sectional area, $A_f$ $[mm^2]$ | |
| Young Modulus, $E$ [GPa] | |
| *Yield Strength, $\sigma_{Y,}$ [MPa] | |
| *Ultimate tensile strength, $\sigma_{UTS}$ [MPa] | |
| *Fracture stress, $\sigma_F$ [MPa] | |
| % elongation | |
| % area of reduction | |

(* it will be read during and after test)

**Plot** the engineering stress-strain and true stress-strain curve on the same graph on a milimetrical paper. Make scales for both x and y axis. Label the known values.

**5. REPORT**

In your laboratory reports must have the followings;

a) Cover

b) A short introduction

c) All the necessary calculations using measured data.

d) Discussion of your results and a conclusion.

**References**

ASM International, Tensile Testing, second edition.

www. mathalino.com / Engineering math review

www.nde-ed.org/ Nde research center

www.azo.com/ Azo materials