BURSA TECHNICAL UNIVERSITY
FACULTY OF NATURAL SCIENCES, ARCHITECTURE AND ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MECHANICAL ENGINEERING LABORATORY

TENSILE TESTING
EXPERIMENT SHEET

Asst. Prof. Dr. Onur SARAY
Asst. Prof. Dr. Sukhwinder Kaur BHULLAR
Res. Asst. Ali Osman GÜNEY

BURSA, 2015
TENSILE TESTING

1. OBJECTIVES

The purpose of this laboratory is to determine characteristic mechanical properties of metals, by performing uniaxial tensile tests using given specimens.

2. GENERAL INFORMATION

Tensile Tests are performed for several reasons. 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. Also, tensile properties often are used to predict the behavior of a material under forms of loading other than uniaxial tension.

Material selection is a central task of the overall design process. Engineers must decide which materials are the most appropriate for a particular design. The tensile test is an important standard engineering procedure useful to characterize some relevant elastic and plastic variables related to the mechanical behaviour of materials.

**Elastic Properties:** When a solid material is subjected to small stresses, the bonds between the atoms are stretched. When the stress is removed, the bonds relax and the material returns to its original shape. This reversible deformation is called elastic deformation. In the elastic region, stress and strain are related to each other linearly and characterized by Young’s modulus, $E$ and the Poisson’s ratio $\nu$.

\[
E = \frac{\sigma_{\text{axial(\text{elastic})}}}{\varepsilon_{\text{axial(\text{elastic})}}}
\]

$\sigma_{\text{axial}}$: engineering stress along the loading axis, $\varepsilon_{\text{axial}}$: engineering strain.

\[
\sigma_{\text{axial}} = \frac{F}{A_0}
\]

where $F$ is the tensile force and $A_0$ is the initial cross-sectional area of the gage section.

\[
\varepsilon_{\text{axial}} = \frac{\Delta L}{L_0}
\]

where $L_0$ is the initial gage length and $\Delta L$ is the change in gage length ($L - L_0$).

In the elastic range, Poisson’s ratio, $\nu$, of the magnitude of the lateral contraction strain to the axial strain:

\[
\nu = -\frac{\varepsilon_{\text{lateral}}}{\varepsilon_{\text{axial}}}
\]
**Plastic Properties**: The plastic behavior of metals, which is dominated by the motion of linear defects such as dislocations and vacancies, plays a central role on assessing the safety conditions of a mechanical system.

**The tensile strength**, or ultimate tensile strength is the maximum load divided by the original cross-sectional area of the specimen:

$$
\sigma_u = \frac{P_{\text{max}}}{A_0}
$$

The tensile strength is the value most frequently quoted from the results of a tension test. Actually, however, it is a value of little fundamental significance with regard to the strength of a metal. For ductile metals, the tensile strength should be regarded as a measure of the maximum load that a metal can withstand under the very restrictive conditions of uniaxial loading.

**Yield strength** is the stress at which plastic deformation or yielding is observed to begin depends on the sensitivity of the strain measurements. With most materials, there is a gradual transition from elastic to plastic behavior, and the point at which plastic deformation begins is difficult to define with precision. In tests of materials under uniaxial loading, three criteria for the initiation of yielding have been used: the elastic limit, the proportional limit, and the yield strength.

**Ductility** is the degree of plastic deformation that a material can withstand before fracture. A material that experiences very little or no plastic deformation upon fracture is termed brittle.

In general, measurements of ductility are of interest in three respects:

- To indicate the extent to which a metal can be deformed without fracture in metalworking operations, such as rolling and extrusion.
- To indicate to the designer the ability of the metal to flow plastically before fracture.
- To serve as an indicator of changes in impurity level or processing conditions.

Ductility measurements may be specified to assess material quality even though no direct relationship exists between the ductility measurement and performance in service.

**Resilience** is the ability of a material to absorb energy when deformed elastically and to return it when unloaded.

**The toughness** of a material is its ability to absorb energy in the plastic range.
**Engineering Stress - Strain Curve:** In the conventional engineering tensile test, an engineering stress-strain curve is constructed from the load-elongation measurements made on the test specimen (Fig. 1). The engineering stress used in this stress-strain curve is the average longitudinal stress in the tensile specimen. The strain used for the engineering stress-strain curve is the average linear strain, which is obtained by dividing the elongation of the gage length of the specimen by its original length.

![Figure 1. Engineering stress-strain curve.](image)

**True Stress - True Strain Curve:** The engineering stress-strain curve does not give a true indication of the deformation characteristics of a metal because it is based entirely on the original dimensions of the specimen, and these dimensions change continuously during the test.

Generally, the metal continues to strain-harden all the way up to fracture, so that the stress required to produce further deformation should also increase. If the true stress, based on the actual cross-sectional area of the specimen, is used, it is found that the stress-strain curve increases continuously up to fracture. If the strain measurement is also based on instantaneous measurements, the curve, which is obtained, is known as a true-stress-true-strain curve.

**Mathematical Expressions for the Flow Curve:** The flow curve of many metals in the region of uniform plastic deformation can be expressed by the simple power curve relation:
\[ \sigma = K \varepsilon^n \]

where \( n \) is the strain-hardening exponent, and \( K \) is the strength coefficient. A log-log plot of true stress and true strain up to maximum load will result in a straight line if Eq 25 is satisfied by the data (Fig. 2). The linear slope of this line is \( n \), and \( K \) is the true stress at \( \varepsilon = 1.0 \). For most metals, \( n \) has values between 0.10 and 0.50.

![Log-log plot of true stress-true strain curve](image)

**Fig. 2.** Log-log plot of true stress-true strain curve \( n \) is the strain-hardening exponent; \( K \) is the strength coefficient.

### 3. TENSILE SPECIMENS AND TESTING MACHINE

A tensile specimen is a standardized sample cross-section. The cross section of the specimen is usually round, square or rectangular. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area (Fig. 3).

![Typical tensile specimen](image)

**Fig. 3.** Typical tensile specimen, showing a reduced gage section and enlarged shoulders.

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.
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. In mechanical engineering laboratory Shimadzu AG-Xplus 250 kN universal testing machine (Fig. 4) is used for tensile testing of specimens.

![Tensile testing machine](image)

**Fig 4.** Tensile testing machine.

The tensile test machine is based on a variable-speed electric motor; a gear reduction system; and 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.

**Procedure:**

- Put gage marks on the specimen
- Measure the initial gage length, width and thickness
- Place the specimen between upper and lower jaw faces.
- Perform the tensile test.
- Get the $F - x$ and/or $\sigma - \varepsilon$ data.
- Measure the final gage length and width.

4. **ASSIGMENTS**

1. Tabulate the data obtained during the test
2. Plot the load versus elongation curve
3. Plot the engineering stress – strain curve
4. Calculate the strength parameters;
   
   4.1 Yield stress (0.2 % off-set), $\sigma_y$ [MPa]
   
   4.2 Young’s modulus, E [GPa]
   
   4.3 Ultimate tensile strength, UTS [MPa]
5. Calculate the critical strains;
   5.1 Yielding strain, $e_y$
   5.2 Strain at onset of neck (Uniform Strain), $e_{UTS}$
   5.3 Fracture strain (Elongation to failure), $e_f$

6. Calculate the energy parameters;
   6.1 Resilience, $U_R$; the elastic energy in J.
   6.2 Toughness, $U_T$; the total energy absorbed by the specimen in J.

7. Convert engineering stress – strain data to true stress - true strain data and plot. Show the calculation steps.

8. Find parameters of $\sigma = K\varepsilon^n$ and compare with that obtained from engineering stress – strain.

REFERENCES


