Laboratory 7

Tensile test

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1. Objectives:

Students are required to:

- Understand the principle of uniaxial tensile testing and gain their practices on operating the tensile testing machine to achieve the required tensile properties.
- Evaluate the values of ultimate tensile strength, yield strength, % elongation, fracture strain and Young's Modulus of the selected metals when subjected to uniaxial tensile loading.
- Explain deformation and fracture characteristics of different materials such as aluminum, or steels when subjected to uniaxial tensile loading.

2. Introduction:

Since mechanical properties are an important measure of product quality, this practical work highlights one of the ways of certifying materials, which is tensile testing. This latest is developed in order to have better information on known materials.

In order to measure a product quality and give it its certifications, materials suppliers need to have mechanical properties data given by a tensile machine. In a broad sense, tensile properties include the resistance of the material for pulling or stretching forces. The strength of a material refers to the ability of a structure to resist loads without failure; this latest may occur by rupture because of excessive stress or may take place due to excessive deformation.

The amount of force required to break a material and the amount it extends before breaking are important properties. For most materials, the initial resistance to force, or modulus, and the point of permanent deformation, are obtained from plots of force against elongation. Analysis of force-elongation or stress-strain curves can convey much about the material being tested, and it can help in predicting its behavior.

3. Equipment description:

The testing machine consists of the following components (figure 1):

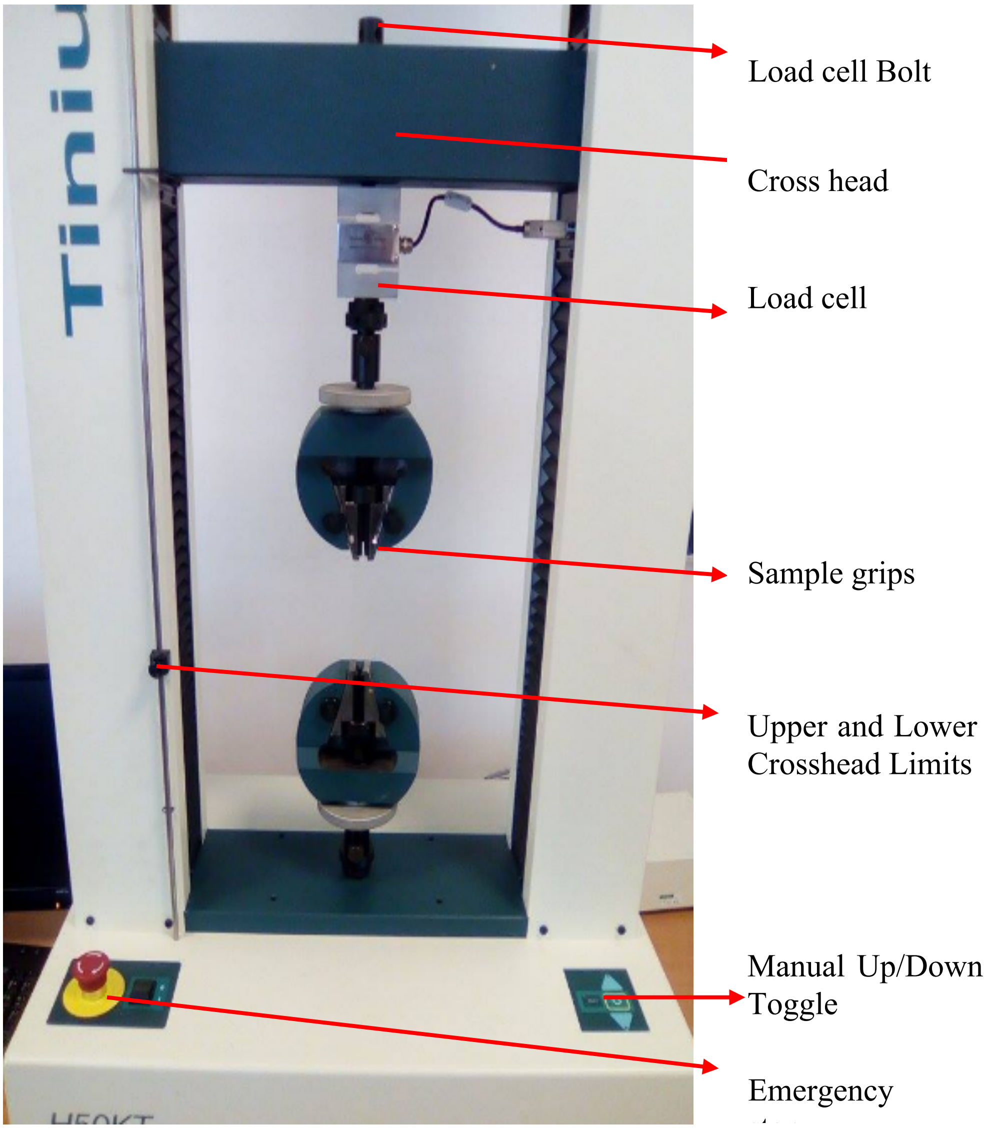


Fig. 7.1 Tensile testing machine Tinius OLSEN H50KT

A- **Loadcell Bolt:** Bolt with hexagonal head for securing the loadcell to the crosshead.

B- **Load cell**: The load cell is fixed to the underside of the crosshead using the bolt supplied. A load cell converts force or weight into an electrical signal, which can then be sent to a remote computer or recorder to monitor load, pressure, strain and more. It is used in diverse industries, such us research laboratories.

C- **Cross head:** - A movable cross head is controlled to move up or down. Usually this is at a constant speed: sometimes called a constant rate of extension (CRE) machine.

D- **Sample Grips:** The sample grips hold the sample during the test. These come in many shapes and sizes.

E- **Upper and Lower Crosshead Limits:** Trip switches for the maximum height the crosshead is allowed to travel during a test.

F- **Manual Up/Down Toggle:** Moves the crosshead up and down manually at the users command.

G- **Emergency Stop:** Safety toggle, pressing will immediately shut down all machine operations.

H- **Output device:** A means of providing the test result is needed (the computer). Some older machines have dial or digital displays and chart recorders. Many newer machines have a computer interface for analysis and printing.

4. Safety Instructions

ATTENTION	**ATTENTION:** Eye protection must be worn during the tensile test.
ATTENTION	Do not begin the laboratory exercise until the Teaching Assistant demonstrates the use of the test equipment.
ATTENTION	Before beginning a test or moving/resetting the Tinius Olsen Tensile Testing Machine, all items including hands, hair, etc. should be clear of machine.
ATTENTION	Put the specimen in a straight position in order to assure uniaxial tensile stress
ATTENTION	Do not exceed the maximum load that could be provided by the machine

5. Formula Symbols and Units Used

Symbol	Mathematical/physical quantity	Unit
σ	Stress: Amount of force exerted per surface area.	Pa
E	Young's modulus: Ratio of Stress over Strain.	Pa
ε	Strain: Extension per unit length.	-
σ_Y	Yield strength	Pa
UTS	Ultimate tensile strength	Pa
σ_R	Fracture strength	Pa
L	Gauge Length	mm
W	Width of the specimen	mm
t	Thickness of the specimen	mm

6. Basic principles

a. Tensile test specimen:

Now that you have known the different components of the tensile testing machine, the next step is to get to know about your specimen. The figure below shows the geometry of a tensile specimen.

The different parts of the specimen must be considered. Firstly, the grip is the section where the load frame grabs the sample and applies the load. The next part is the gauge length, the deformation will occur here. The gauge length of the sample has a cross-sectional area that the load will be applied across, generating a stress.

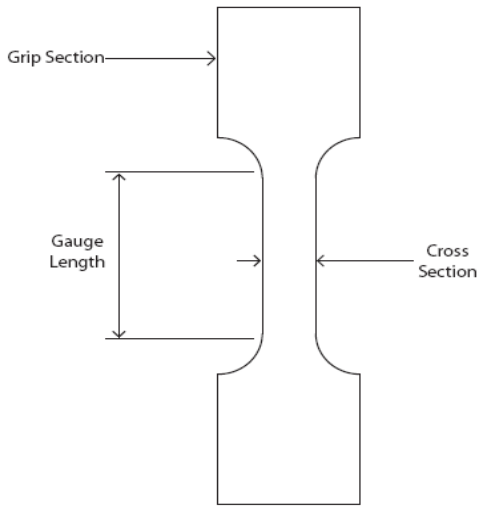


Fig. 7.2 Tensile test specimen

b. Basic information about tensile testing

While applying a force system, mechanical properties of materials can be revealed. Often, these properties depend on the temperature and the loading rate. For example, for metallic materials, the mechanical properties can be subdivided to elastic and plastic properties. In general, elastic properties are less sensitive to temperature variations and loading rates.

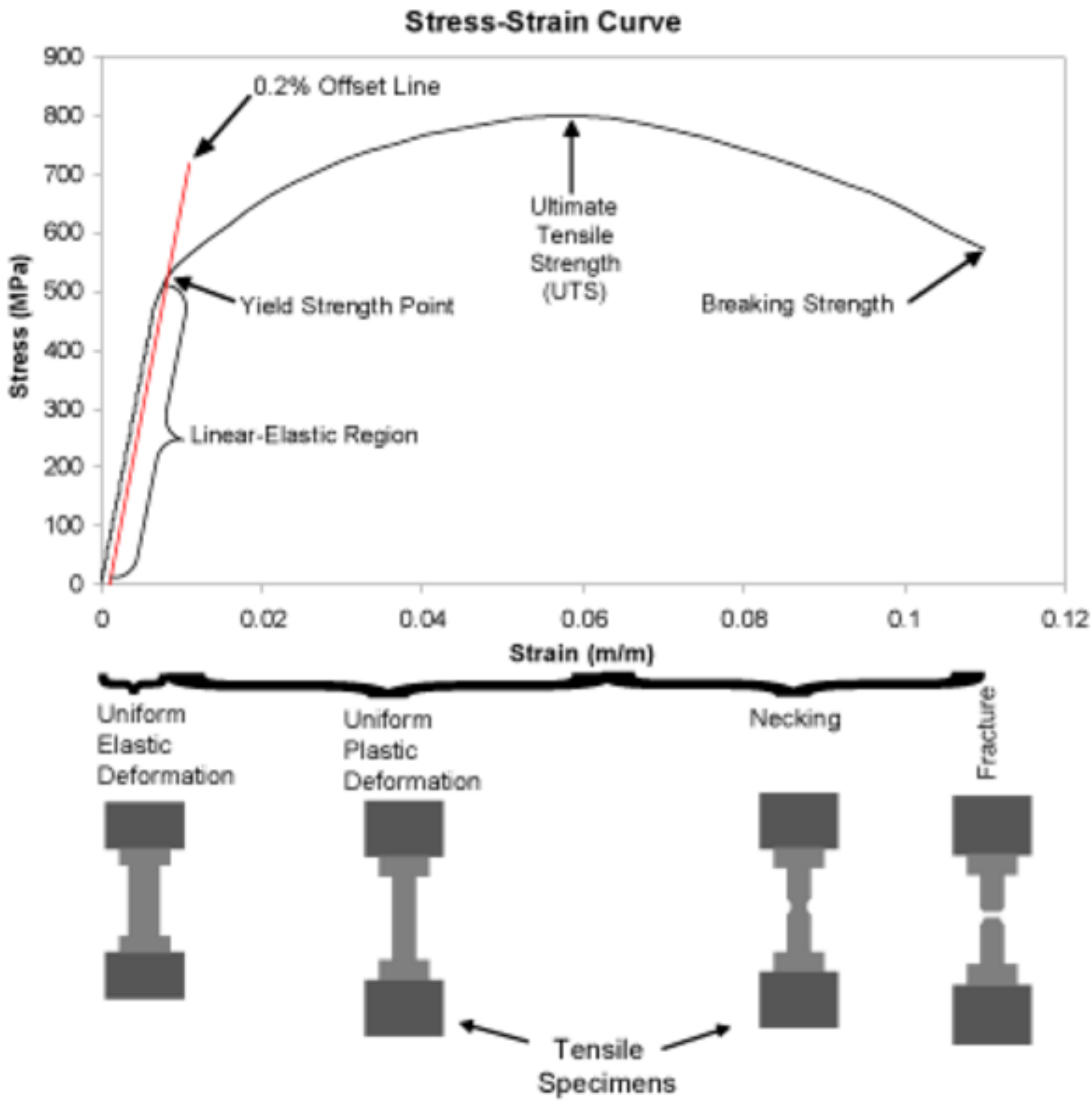


Fig. 7.3 Typical product of a tensile test

The figure 7.3 shows the typical product of a tensile test, which is a load versus elongation curve. This latest is converted into engineering/true stress versus engineering/true strain curve as can be seen. The engineering stress and the engineering strain are obtained by dividing the load and elongation by constant values (initial specimen geometry information). On the other side, the true stress-strain is the load-elongation divided by the cross-area at that instant.

The stress strain curve relates the applied stress to the resulting strain; each material has its own unique stress-strain curve.

From this engineering stress strain curve, it can be seen that the stress and strain increase with a linear relationship. This region indicates that no plastic deformation occurs. When the material is deformed, it will return to its original shape.

The elastic properties include the Young's modulus (E), which defines the properties of a material as it undergoes stress, deforms, and then returns to its original shape after the stress is removed. It is a measure of the stiffness of a given material. To compute the modulus of elastic region, simply divide the stress by the strain in the material as Hook's law shows.

Hooks law: $\sigma = E * \varepsilon$

Yield point:

In the case of ductile materials, the stress-strain curve deviates from the straight line and Hooks law is no longer applied as the strain increases faster than the stress. From this point, permanent deformation occurs in the specimen and the material reacts plastically to any further increase in load or stress. On the other side, for brittle materials, little or no plastic deformation occurs and the material fractures near the linear elastic region of the curve.

For most materials, there is a gradual transition from elastic to plastic behavior, the exact point at which the plastic deformation occurs is hard to determine. For most applications, the yield strength is used and is defined as the stress required to produce a small amount of plastic deformation. The offset yield strength is the stress corresponding to the intersection of the stress-strain curve and a line parallel to the elastic part of the curve offset by a specified strain (0.2%). "That intersection is defined as the yield strength with a 0.2% offset."

The Ultimate tensile strength:

The ultimate tensile strength (UTS) or, more simply, the tensile strength, is the maximum engineering stress level reached in a tension test. On the stress strain curve, it is the highest point where the line is momentarily flat.

- For brittle materials, the UTS will be at the end of the linear-elastic portion of the stress-strain curve or close to the elastic limit.
- For ductile materials, the UTS will be well outside of the elastic portion into the plastic portion of the stress-strain curve.

The UTS is not the same as the breaking strength. For example, in ductile materials the strain hardening occurs and the stress will continue to increase until the fracture takes place.

Measurement of the ductility of a material:

Tension is one of the ways that are used in loading a material. Several standard tests have been established in order to characterize the behavior of a material under other loading conditions, such as; bending, compression, torsion …

Ductility is more commonly defined as the ability of a material to deform easily upon the application of a tensile force, or as the ability of a material to withstand plastic deformation without rupture. Its measurement is of interest to those conducting metal forming processes, to designers of machines and structures, and to those responsible for assessing the quality of a material as it is being produced.

During the tensile testing, before the specimen breaks it has stretched out a great deal, and has necked down in the area where it breaks. The amount it had stretched when it broke is the **"% Elongation"**, and the amount it necked down is the **"% Reduction of Area"**. These are the most common means of measuring the ductility.

% Elongation:

$$\text{Percent elongation} = \frac{\text{final gage length} - \text{initial gage length}}{\text{initial gage length}}$$

% Reduction of Area:

$$\text{Percent reduction of area (RA)} =$$

$$\frac{\text{area of original cross section} - \text{minimum final area}}{\text{area of original cross section}}$$

Because the elongation is not uniform over the entire gage length and is greatest at the center of the neck, the percent elongation is not an absolute measure of ductility. The reduction of area, being measured at the minimum diameter of the neck, is a better indicator of ductility.

7. Experimental Procedure

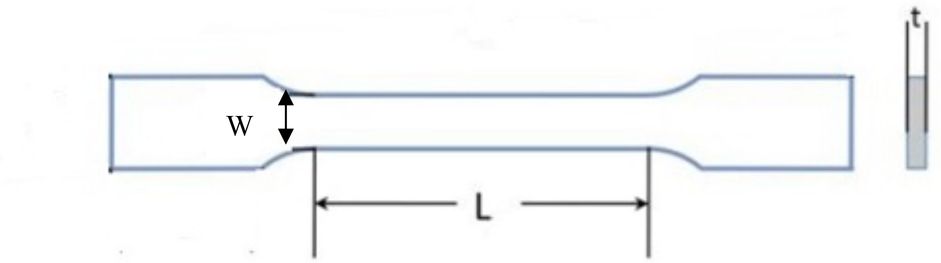
1- <u>Configuration of the software</u>:

- Click on the horizon icon, then the software starts
- Verify that no previous test appear in the main window,

  If it is the case, you need to delete all the previous tests by clicking on X.
- Add a new test by clicking on
- On the tab options, select the method: generic tensile-stress versus strain
- Select: single mode

2- <u>Measurement of the sample's geometry</u>:

The specimens provided are steel and aluminum. Before loading the specimen in the machine, use the caliper and measure the dimensions of the given samples as mentioned in the following image. Write these dimensions down.



W: Width
L: Gauge length
t: thickness

3- <u>Mounting of the specimen in the tensile machine:</u>

- Insert the sample in the bottom grip. Hold the sample vertical, and tighten the bottom clamp by turning the disk in this direction ←.
- Be sure that the sample is tightened very well, if it is not well adjusted, it can be sided during the experiment, thus, the curve will be deformed. Adding to this, be wary when tightening to not bend your sample.
- Using the up/down toggle, lower the crosshead manually until your sample is in the right position (between the top sample grips) and tighten the top clamp by turning the disk in this direction →, again, be careful not to bend your sample during tightening.
- Ensure that both clamps are very well tightened.

4- <u>Running the software:</u>

- Insert the dimensions of the specimen

- Reset the values of the force and the position
- Run the test by clicking on 
- Wait until you reach the failure of the specimen

5- **Save the stress-strain** curve obtained and compute the following properties for each sample:
- Young's modulus
- Yield strength
- Ultimate tensile strength
- Breaking strength / Fracture stress

8. Questions

1- Do the experiment as described in paragraph 7 for Aluminum, Steel and copper specimens.
2- Discuss the obtained experimental results and give an analytical evaluation of the relationship of the stress distribution and the loading and model shape.

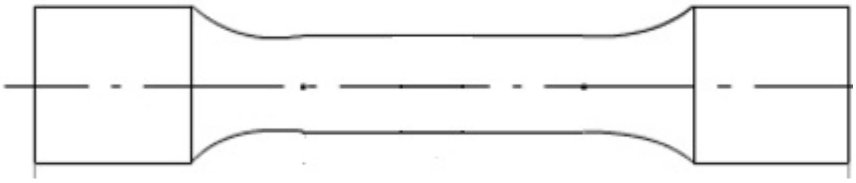
9. Results

a. Dimensions of the specimens:

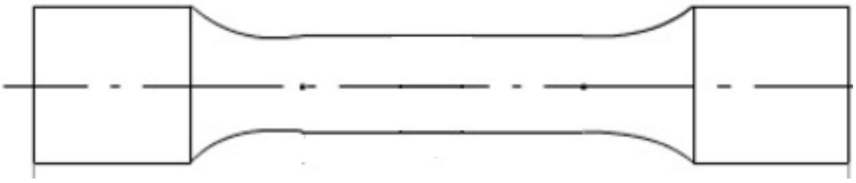
Material	Undeformed			Deformed		
	Width ***mm***	**Thickness** ***mm***	**Gage length** ***mm***	**Width** ***mm***	**Thickness** ***mm***	**Gage length** ***mm***
Aluminum						
Steel						
Copper						

Samples:

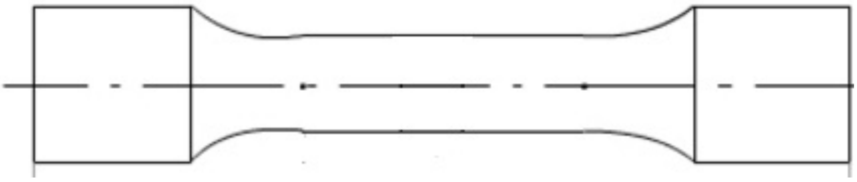
Aluminum:



Steel:



Copper:



b. Stress- strain curves:

c. Material's properties:

d. Analysis: