

Lab course session

Uniaxial tensile test on dogbone specimens

April 2023

1 Introduction

The mechanical properties of materials are determined by performing carefully designed laboratory experiments aimed at inducing a certain state of stress or deformation. Among the common test cases, tensile loading is one of the most important tests.

In this session, we want to perform a uniaxial tensile test on a dogbone specimen to determine the following physical quantities:

- Stress vs. engineering strain curve and stress vs. real strain curve
- Tensile strength (σ_{UT})
- Young's modulus (E)

To perform the test, we use a universal testing machine by INSTRON (Model 8862 with ± 100 kN loading capacity) as shown in Figure 1. The type of fixtures used in this machine can be changed to accommodate tensile, compressive, and flexural experiments. In this session, we deal with the tensile setup. The data obtained from this test are the load (F) measured by the load cell, the machine displacement (d) and, if a crack-mouth opening displacement (CMOD) gauge is installed, the elongation Δ of a portion of material with length equal to the gauge length L_G (in our case $L_G = 10$ mm). A typical load-displacement curve obtained with a dogbone specimen is shown in Figure 2.

The (engineering) stress and strain along the longitudinal direction can be obtained as

$$\sigma = \frac{F}{A_0}, \quad (1a)$$

$$\varepsilon = \frac{\Delta}{L_G}, \quad (1b)$$

where $A_0 = w_0 \times t_0$ is the initial cross-sectional area. The real strain can be obtained as

$$\varepsilon = \frac{\Delta}{L_G + \Delta} = 1 + \frac{\Delta}{L_G} = 1 + \varepsilon. \quad (2)$$

To obtain the tensile strength, it is enough to find the peak load (as illustrated in Figure 2), and then divide it by the initial area A_0 . Also, to identify the flexural modulus of the tested material, it is customary to consider as linear elastic region the part of the engineering strain vs. stress curve within a range of 20% – 60% of the peak load. Therefore, the Young's modulus E can be obtained as the slope of the linear relation best-fitted to the linear range of the stress-strain data points.

2 Specimen

A common specimen type used for uniaxial tensile tests is the *dogbone* specimen (Figure 3). During a typical tensile test, the dogbone specimen is gripped at its two ends while being pulled to elongate at a determined rate until its failure.

2.1 Specimen preparation

The dogbone specimens have already been manufactured and are available in the lab. Pick one specimen and mark the longitudinal and transverse centre lines on its surface. To mount the CMOD gauge, we firstly need to install two *knives* on the specimen. To this end, mark the positions where the knives must be installed at the center of the specimen accounting for a $w_0 = 10$ mm gap between the edges (Figure 3). Afterwards, use super glue to rigidly attach both knives to the specimen. The specimen is now ready for the experiment.

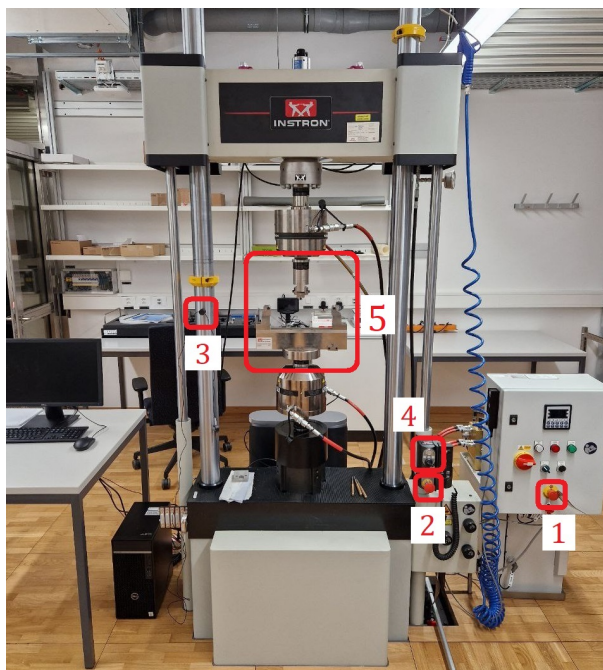


Figure 1: INSTRON universal testing machine. #1, 2: Stop emergency buttons; #3: Holder for securing the wire of the crack-mouth opening displacement gauge; #4: The switch for setting the power mode of the machine; #5: The fixtures of the machine.

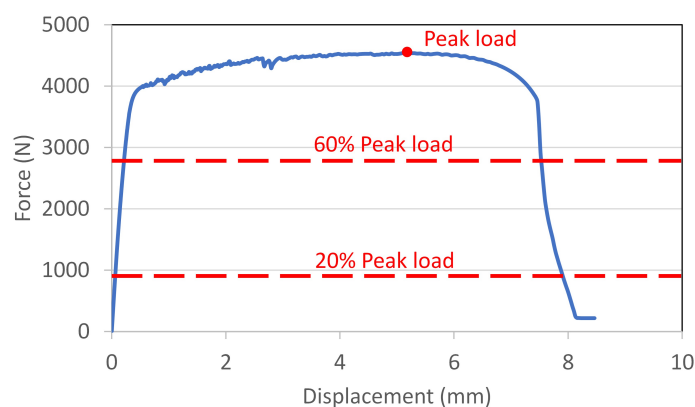


Figure 2: A typical load-displacement curve obtained for a dogbone specimen.

2.2 Specimen dimensions

Use a calliper to measure the following dimensions. Take note of these measurements:

- Initial width of the gauge region (w_0): *mm*
- Initial thickness of the gauge region (t_0): *mm*
- Gauge length, i.e. initial distance between the centres of knives (L_G): *mm*

3 Test setup and execution

3.1 Safety measures

To ensure the safety of yourself and your group members, please follow the indications of the present guidelines and of the supervisor very carefully. In case of an emergency situation with the machine, press one of the two red buttons marked with #1, 2 in Figure 1. Wear **protective glasses** before you

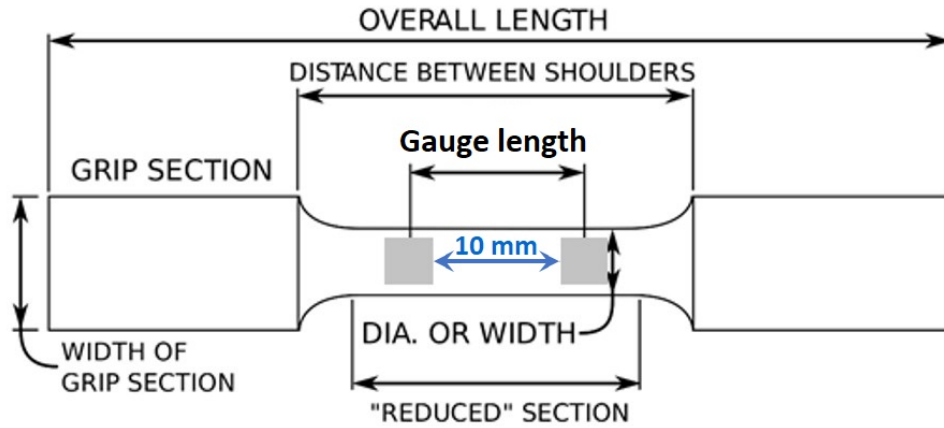


Figure 3: Dogbone specimen for uniaxial tensile test and its key dimensions.

start working in the lab.

To work with the grips and fixtures of the machine, or to position the specimen inside the grips, make sure that the machine is in **standby** mode. To change the power mode of the machine, use the switch represented by #4 in Figure 1. The left status is for *standby* mode. The middle one is for *low-power* mode, which can be used to run the machine with the hand controller. The right status is for *high-power* mode where the computer software can be used to run the machine.

3.2 Fixtures, specimen positioning and CMOD installation

Put the machine in standby mode via rotating the switch denoted by #4 (in Figure 1) to its leftmost position. With the help of the present supervisor, change the fixtures of the machine (#5 in Figure 1) and install the ones suitable for tensile tests, as demonstrated in Figure 4a. Put the machine in the low-power mode by rotating the switch denoted by #4 to the middle position and by pushing the green flashing button until the light becomes static. Bring down/up the actuator of the machine to adjust the distance between the upper and lower grips with respect to the length of the dogbone specimen. Put the machine back in standby mode. Install the dogbone specimen inside the grips while you observe the coincidence of the longitudinal centre line with the central hole on top of the grips. After the installation of the specimen, use the hand controller shown in 4b to apply hydraulic pressure on the grips so that the specimen is firmly fixed in its position. On the hand controller, the upper and lower buttons operate the upper and lower jaws, respectively. To apply pressure on the specimen, press the black buttons upward, and, to remove the pressure, press the buttons downward. Last but not least, mount the CMOD gauge on the knives that you previously glued to the specimen.

Attention: Since the CMOD gauge is very precise and expensive equipment, please make sure to deal with it with extra care. Particularly, please secure the wire by positioning it inside the groove of the cylindrical black holder on the left column of the machine (see #3 in Figure 1).

3.3 Settings of the machine and running the test

Once the specimen is placed inside the grips and the grips are pressurised by the hydraulic system, it is time to start with the main part of the test.

Do the following steps:

1. Run *Instron Console* software (see Figure 5 (a)). Change the running status of the machine to high-power via rotating the switch denoted by #4 (in Figure 1) to its right-most position.
2. In Console, in *Linear*, press *Load_100kN* and then select *Calibration*. Run the *Calibration Wizard* and chose *Auto Calibration* to automatically calibrate the load cell (Figure 5 (b)). Follow on-screen instructions and wait for the calibration process to finish. Repeat the same procedure to calibrate the CMOD gauge, by clicking on *Strain 1* (right beneath *Load_100kN*).

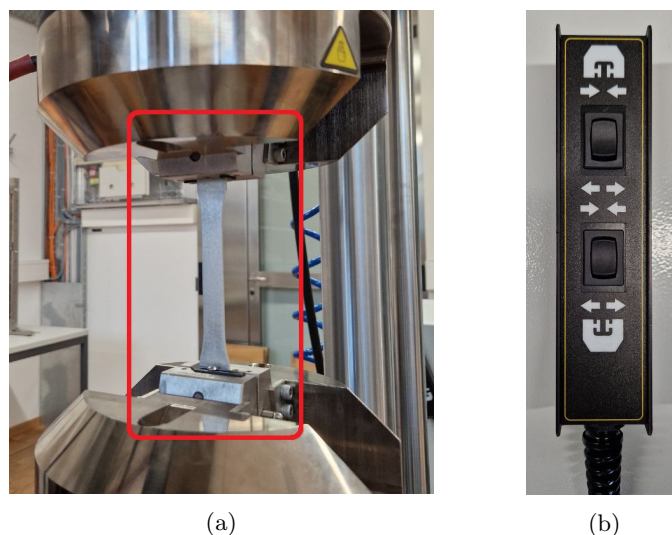


Figure 4: (a) Fixtures configuration and positioning of the dogbone specimen. The red rectangle indicates the specimen along with the upper and lower grips; (b) the hand controller for activating/deactivating the hydraulic pressure on the grips.

3. Run *Bluehill Universal* software (Figure 6 (a)). Click on *Test* (Figure 6 (b)) and from the *New sample* section, look for the existing method *ExpMech_Dogbone* and select it (Figure 6 (c)). This method has been already created with specific considerations for the uniaxial tensile test on dogbone specimens.
4. Go to the *Method* tab (see Figure 6 (d)). Under *Test Control* select *Test*. Make sure that the test is Displacement-controlled whereby *Control mode 1* should be set to *Displacement*. Furthermore, double-check that *Rate 1* is not more than 1 mm/min. Also, go to *Export* tab (Figure 6 (e)) and define a directory for saving the test data for your group (preferably inside `C:\Users\ETH ZURICH\Desktop\ExpMech\StudentsTests\GroupNumber`).
5. According to Figure 6 (f), go back to the *Test* tab and click on *Balance all* so that all the readings from the sensors become zero. To begin the experiment, press the *Start* button.
6. Observe the live graphs on the screen and try to identify the linear elastic region, and afterwards, the transition to the plastic behaviour. Wait until the test completes when the specimen ruptures into two pieces. Put the machine in standby mode and take out the specimen pieces from the grips by depressurising the hydraulic jaws (which can be done by pressing the buttons downward, on the controller shown in Figure 4b).

4 Questions and analysis of data

Using the data obtained from your experiment, we ask you to prepare an individual lab report including the following information

1. Load vs. the displacement of the machine.
2. Load vs. the CMOD gauge measurement.
3. Peak load, show it on your load-displacement curve
4. Measured tensile strength.
5. Stress vs. the engineering strain curve.
6. Stress vs. real strain curve.
7. Measured Young's modulus.

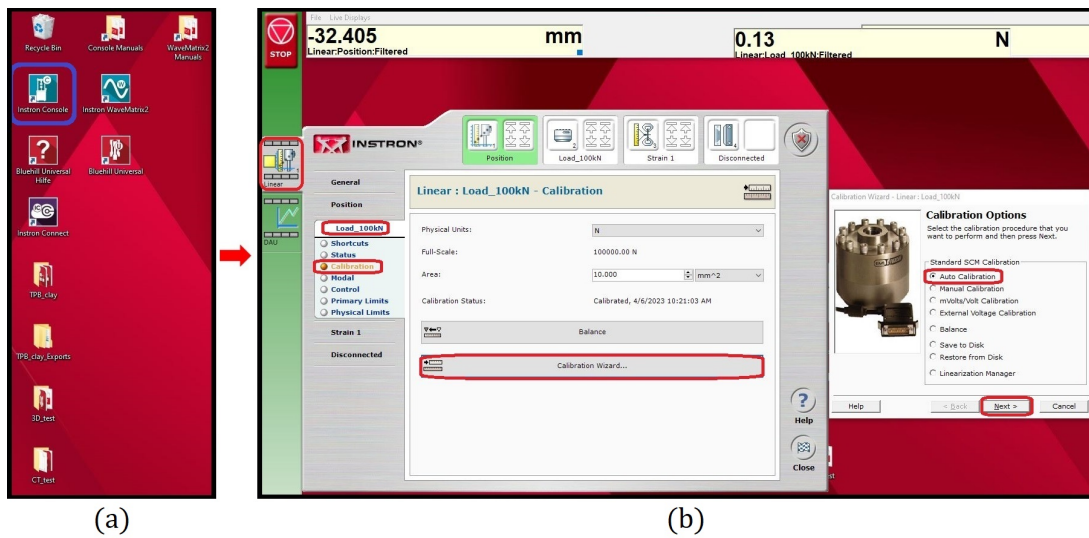


Figure 5: (a) Running the Instron Console software and (b) auto-calibrating the load cell.

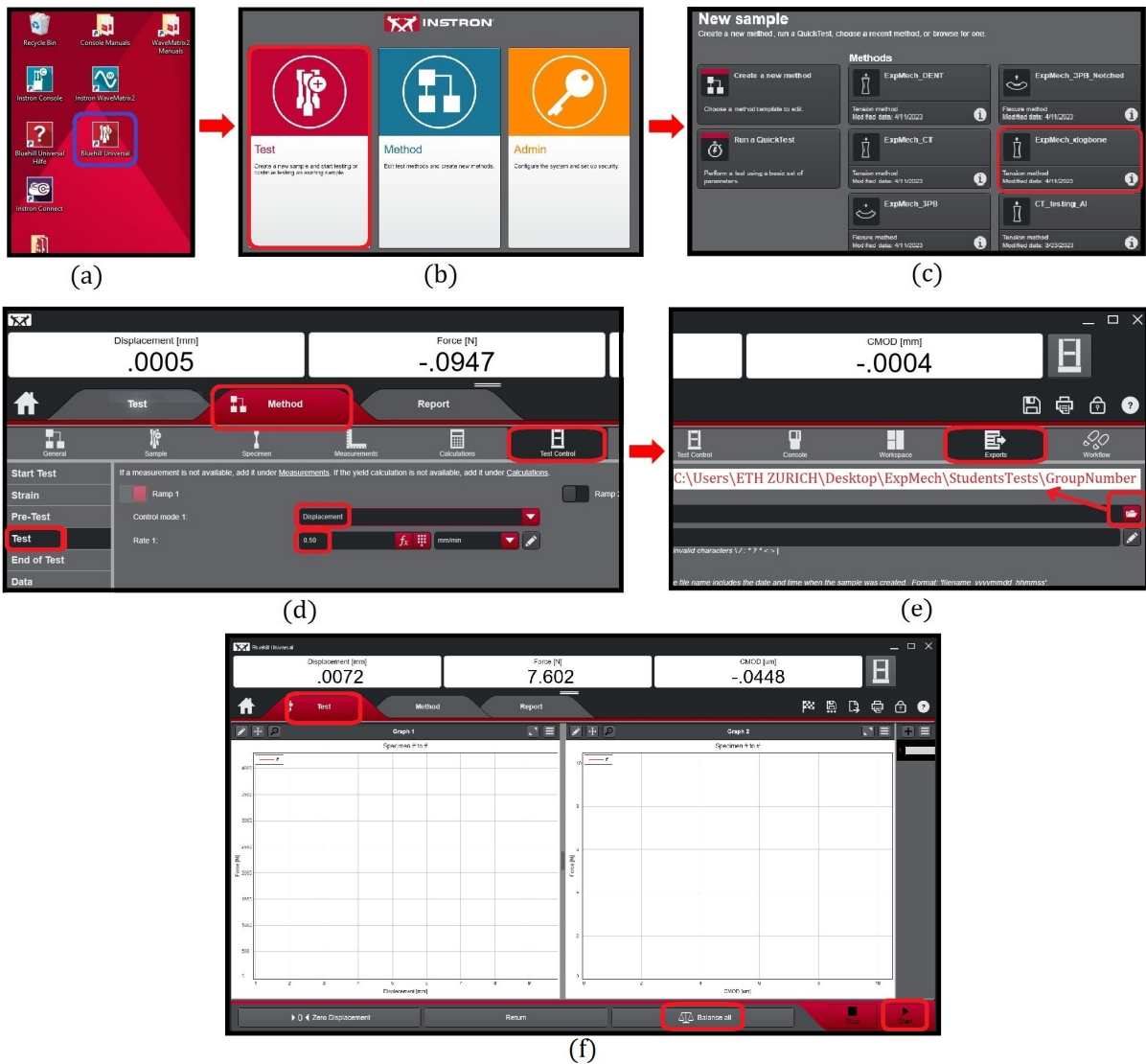


Figure 6: (a) Running the Bluehill Universal software; (b) defining a new test; (c) selecting the suitable method; (d) controlling the test and rate; (e) defining the export path for the test data; (f) balancing all the readings and running the test.