30.001: STRUCTURES AND MATERIALS

Tensile Experiment Training

1. OBJECTIVES

i. To study the principles and procedure of a tensile test via using the Instron materials-testing system.

ii. To understand the relationship between the stress and strain properties of a material.

2. INTRODUCTION

Mechanical properties of a material are typically determined via a carefully designed laboratory experiment that closely resembles the actual conditions experienced by the material in the real-life application. The material may be subjected to various loads, such as tension, compression, or shear. Understanding these properties are highly important in the selection of materials for mechanical design.

In this experiment, we investigate the tensile properties of metals, glasses, and polymers. Figures 2.1-2 show one of the tensile testing machines employed in this lab. In a typical experiment, a dog-boned shaped sample (ASTM E8 standard, see Fig. 2.3 and Appendix) is clamped at its two ends, and pulled to elongate at a determined rate to its breaking point (note a highly ductile polymer may not reach its breakpoint). For this lab, we will employ the flat-type test samples, although the round/cylindrical-type samples could also be used. The tensile testing machines used in this lab are Instron 5943 and 5982, with a maximum load of 1 kN and 100 kN, respectively.

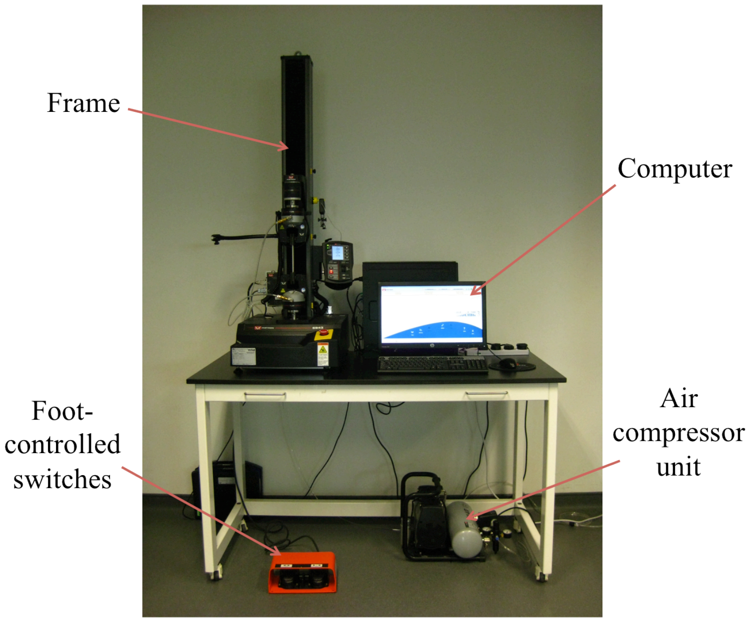

Fig. 2.1. Set-up of the Instron 5943 materials-testing system.

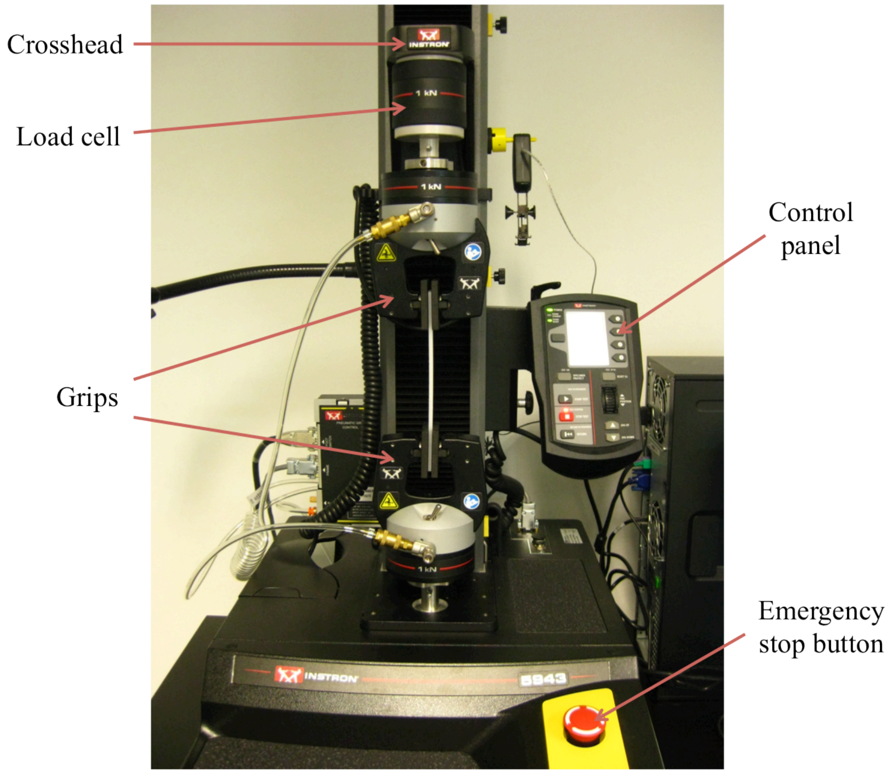

Fig. 2.2. Close-up image of the materials-testing system.

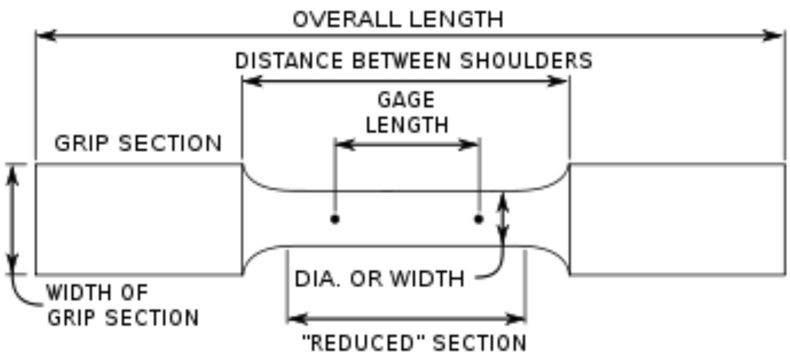

Fig. 2.3. Schematic of a dog-bone shaped sample.

To study the tensile properties of a material, a plot of engineering stress (σ) as a function of engineering strain (ε) is constructed during the tensile test experiment, which can be calculated using computer software (e.g. Instron's Bluehill) provided by the instrument manufacturer. Engineering stress, in the metric system, is normally measured in N/m^2. The engineering stress value is calculated via the ratio of the force (F) applied by the machine in the axial direction to a *constant, initial* cross-sectional area (A) of the material:

$$\sigma = \frac{F}{A} \tag{2.1}$$

The engineering strain value, which has no units, is given by ratio of the change in the length of a material to its initial, unstressed reference length:

$$\varepsilon = \frac{L - L_0}{L_0}, \tag{2.2}$$

where L_0 and L are the instantaneous and initial lengths of the material.

In reality, both "true" stress and strain values are different from those calculated using the above equations, due to the fact that when a material reaches its *ultimate stress strength*, its cross-sectional area *reduces* with elongation, in a process known as *necking*. Theoretically, the true stress-strain curve can be constructed by assuming that the volume of the material remains unchanged during the experiment. The true stress value is given by:

$$\sigma_T = \sigma \frac{L}{L_0}, \tag{2.3}$$

where σ refers to the instantaneous stress. For true strain, the value can be calculated via:

$$\varepsilon_T = \ln\left(\frac{L}{L_0}\right) \tag{2.4}$$

3. EXPERIMENTAL PROCEDURE

3.1. SAFETY PRECAUTIONS (***Important!)***

i. Always wear **safety glasses** when operating the machine. Depending on the material under test, fragments may project out of the samples and present a projectile hazard.

ii. Only **1 student** should operate the testing system at any time.

iii. In the unlikely event of an incident during the loading or testing of a sample, halt the experiment immediately via pressing the **emergency-stop button**, and report the incident to the nearest instructor.

iv. Mind your **fingers** during the loading/unloading of the samples.

v. Keep a **distance** away (~1.5 m) from the machine when an experiment is running.

3.2. SAMPLE PREPARATION

i. Note both **thickness** and **width** of the material samples (in millimeters). Although the thicknesses of the samples may vary, for this experiment, we will assume the sample thickness to be 5 mm, which is within the specific range.

ii. Record the **weight** of the samples.

iii. Make note of any sample defects (e.g. impurities, air bubbles, etc.).

3.3. START-UP

i. Switch on **air compressor unit** (JUN-AIR) that is located below the Instron 5943 system (turn the black knob from the OFF to AUTO position). This will activate the pneumatic grips for clamping the test samples.

ii. Turn on **frame** via a switch located behind its base (on the right side), and wait for the system to run its calibration process (an hour glass will appear on the screen of the control panel) (see Fig. 3.3.1).

Fig. 3.3.1. Image of the screen of the control panel during system calibration.

iii. Check both **Power** and **Frame-standby** indicator lights on the control panel, which should turn to GREEN and RED after completion of the calibration process, respectively (refer to Fig. 3.3.2).

Fig. 3.3.2. Image of the power and frame-standby indicator lights.

iv. Run **Instron Bluehill 3 software** from the computer desktop. This activates the frame and makes the control panel available for use (see Figs. 3.3.3-4).

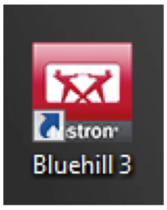

Fig. 3.3.3. Image of Bluehill 3 software icon.

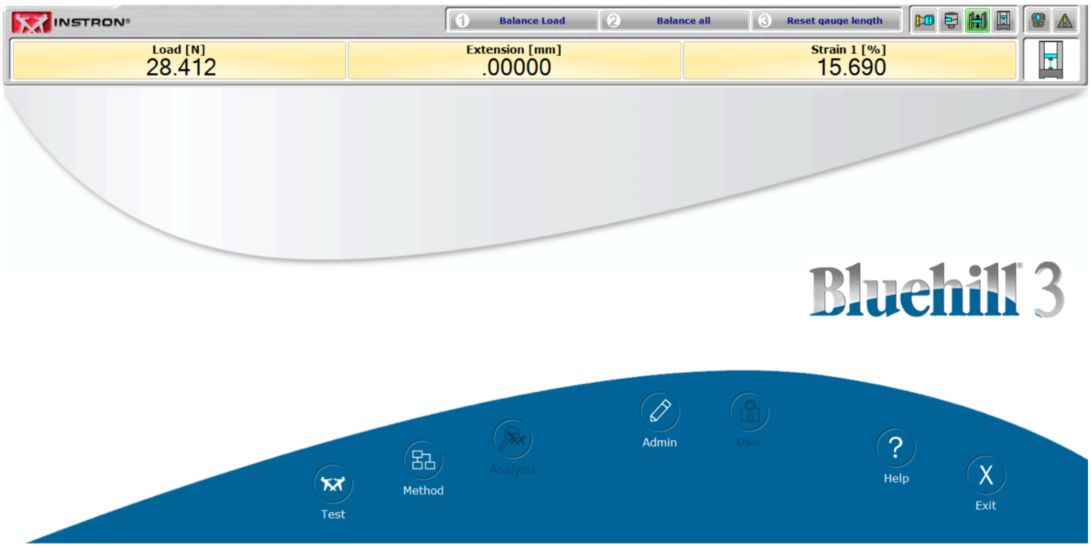

Fig. 3.3.4. Image of home page for the Bluehill 3 software.

v. Check **Frame-ready** indicator light. It should display GREEN, and the system is ready for use, as shown in Fig. 3.3.5.

Fig. 3.3.5. Image of the power and frame-standby indicator lights when the system is ready.

3.4. SOFTWARE SETTINGS

i. Click **Test** icon, as shown in Fig. 3.4.1.

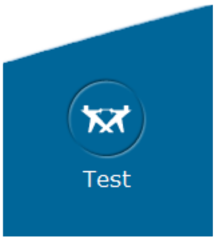

Fig. 3.4.1. Snapshot of the test icon.

ii. Under Create a new sample, Method name, select "**Tensile-Testing-Lab.im_tens**" and click **Next** (Fig. 3.4.2).

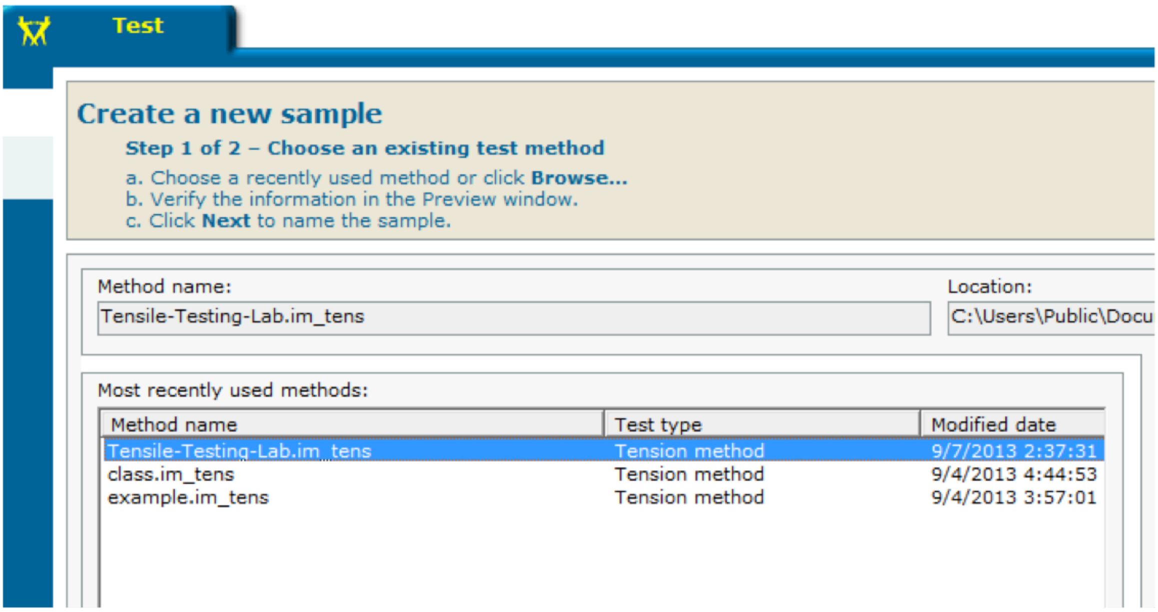

Fig. 3.4.2. Snapshot of the 'Create a new sample' page.

iii. For Name the new sample, type in a **name** for the sample, and click **Next** (Fig. 3.4.3)

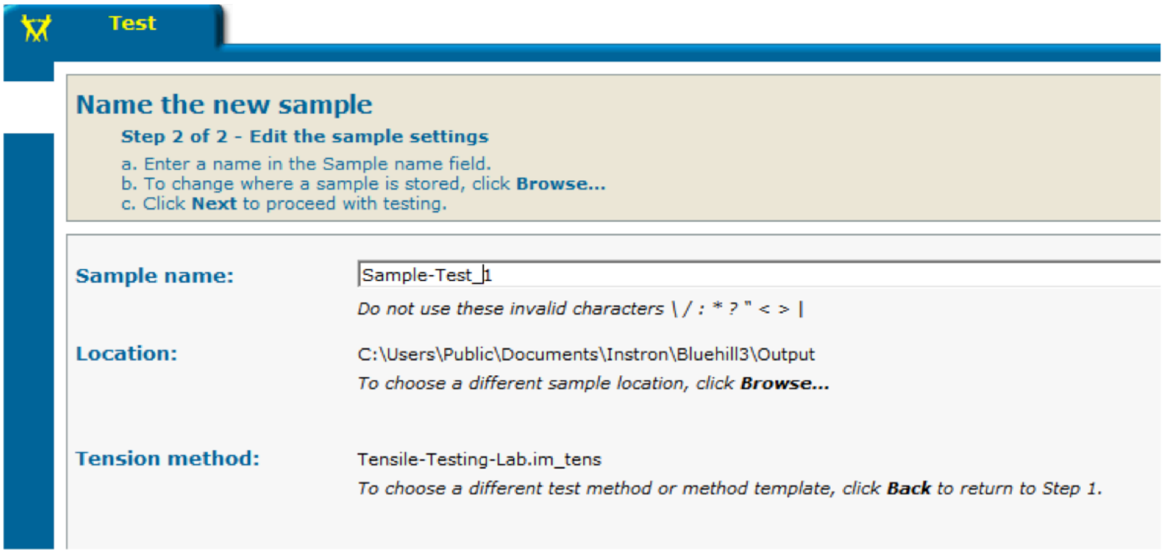

Fig. 3.4.3. Snapshot of the sample-name input page.

3.5. INSRUMENT SETUP

i. Click **Balance-load** in the Bluehill software (top panel) to initialize the load to zero (see Fig. 3.5.1).

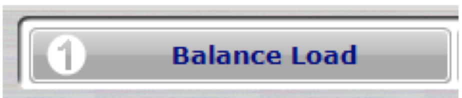

Fig. 3.5.1. Snapshot of the Balance-load icon.

ii. Clamp test sample between the top and bottom grips using the **foot-controlled switches** (BEWARE OF YOUR FINGERS!) (The sample should be clamped such that the two ends of the sample are covered by the grip, about 90 mm apart). Ensure that the sample is tightly clamped to prevent slipping, which will result in experimental errors.

iii. Make sure that the sample is vertically aligned, if not a torsional force, rather than an axial force, will result.

iv. Check both **Load** and **Extension** values from the Bluehill software. If the sample is clamped under certain tensile/compressive load, press **Specimen-protect** button on the control panel to allow the system to automatically adjust the load to within ±10 N (Fig. 3.5.2). When this is completed, press the same button again to finish the process.

Fig. 3.5.2. Image of the specimen protect

v. Click **Balance-all** in the Bluehill software to set both Load and Extension values to zero, as shown in Fig. 3.5.3.

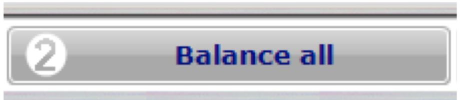

Fig. 3.5.3. Snapshot of the Balance-all icon.

vi. Under Operator inputs (top right box), enter the **width**, **thickness**, and **length** *(distance between the top and bottom grips)* of the sample, as shown in Fig. 3.5.4.

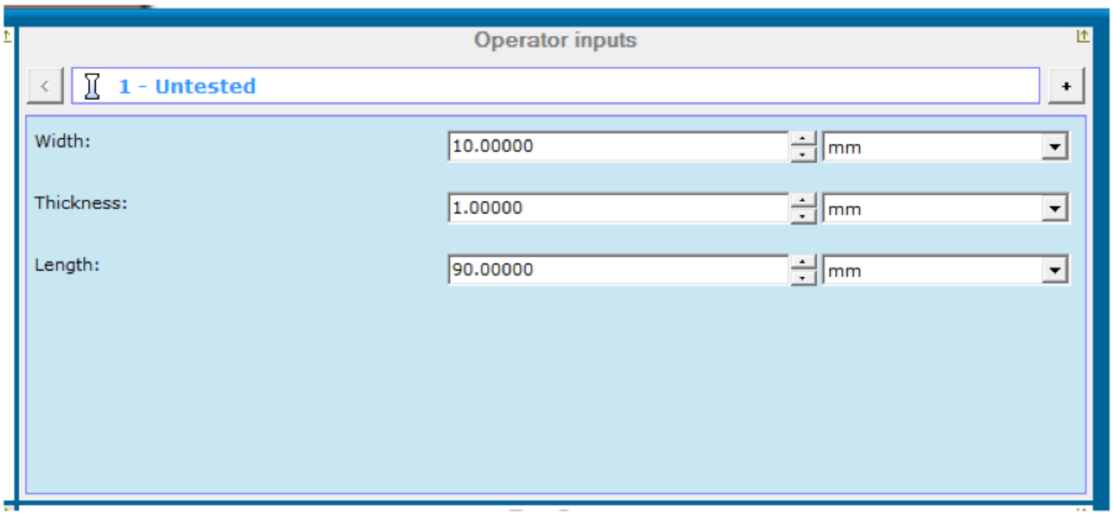

Fig. 3.5.4. Snapshot of the parameter settings box.

3.6. TENSILE TEST

i. Click **Start** and testing will begin (Fig. 3.6.1). Both top and bottom grips will start to move in the opposite directions at a specified rate, which results in the elongation of the material. (KEEP A DISTANCE AWAY FROM THE MACHINE!)

Fig. 3.6.1. Snapshot of the Start icon.

ii. Observe the experiment and take not of the failure mode when the sample fails.

iii. A plot of engineering stress against engineering strain will be constructed in-situ during the experiment.

3.7. END OF TEST

i. The machine will **stop** automatically when the sample is broken.

ii. **Remove** the sample with the foot-controlled switches.

iii. To perform a **new** experiment, return to section 3.5 (INSRUMENT SETUP), and repeat the test procedure.

3.8. DATA SAVE AND RETRIEVAL

i. Click **Finish** to save the raw data (Fig. 3.8.1).

Fig. 3.8.1. Snapshot of the Finish icon.

ii. Select **No** if prompted to Start another new sample.

iii. Also, choose **No** if prompted to Save changes to test method.

iv. **Close** the Bluehill software.

v. Click **Output-Shortcut** button on the desktop computer. Retrieve the data required.

Fig. 3.8.2. Snapshot of the Output-Shortcut icon.

3.9. POWER-OFF SYSTEM

i. Ensure Bluehill software is **close.**
ii. Switch off **frame.**
iii. Turn off **air compressor unit.**

4. POSSIBLE EXERCISES

i. Using the raw data collected, calculate and plot the engineering stress as a function of engineering strain for all materials samples.
ii. Derive the equations for both true stress and true strain of a material.
iii. Calculate and construct the true stress-strain curves for all samples.
iv. Discuss any difference in mechanical behaviour between the materials.
v. Analyze the fracture mode of each sample.
vi. Discuss any unexpected results.

REFERENCES

i. R. C. Hibbeler, Mechanics of materials, Ninth edition, Pearson Prentice Hall Inc., 83-91 (2013).
ii. M. F. Ashby, D. R. H. Jones, Engineering materials, Fourth edition, Elsevier Ltd., 119-122 (2012).

APPENDIX

Table A. Specimen dimension (Note all values in inches, sheet type, 0.5 in. wide)

Gage length	2.00±0.005
Width	0.500±0.010
Thickness	$0.005 \leq T \leq 0.25$
Fillet radius (min.)	0.25
Overall length (min.)	8
Length of reduced section (min.)	2.25
Length of grip section (min.)	2
Width of grip section (approx..)	0.75