Lab Exercise #2: Tension Testing (Uniaxial Stress)

Learning Outcomes:
1. Understand the basic concepts of stress and strain
2. Identify the engineering material properties
3. Connect stress and strain through Hooke's Law and Young's Modulus
4. To be able to generate stress-strain diagrams for samples experiencing tension
5. The ability to analyze and interpret data

Principles:
Tensile testing is one of the more basic tests to determine stress – strain relationships. A simple uniaxial test consists of slowly pulling a sample of material in tension until it breaks. Test specimens for tensile testing are generally either circular or rectangular with larger ends to facilitate gripping the sample.

The typical test is to deform or "stretch" the material at a constant speed. The required load that must be applied to achieve this displacement will vary as the test proceeds. The **stress** in the sample can be calculated by dividing the load by the initial cross-sectional area ($\sigma = P/A$). The displacement in the sample can be measured at any section where the cross-sectional area is constant. The **strain is calculated by taking this change in length and dividing it by the initial length ($\varepsilon = \Delta L/L0$).** Engineering stress and strain (constant cross section) will be recorded, as opposed to the actual, (variable cross section). This is because the actual cross section of the specimen is very difficult to measure.

Engineering material properties that can be found from simple tensile testing include the **elastic modulus** (modulus of elasticity or Young's modulus), **ultimate tensile strength** (tensile strength), **yield strength**, **fracture strength**. These values are typically calculated in tension experimentation and compared to published values.

The **modulus of elasticity** can be calculated by finding the slope of the stress-strain curve where it remains linear and constant. Where the stress-strain curve starts to become non-linear, this is known as the **proportional limit**. The proportional limit is also the point where **yielding** occurs in the material. At this point, the material no longer exhibits elastic behavior and permanent deformation occurs. This onset of inelastic behavior is defined as the **yield stress** or yield strength. Some materials (such as the steel used in this lab) will have a well-defined yield point that can be easily identified. Other materials will not have a discernable yield point, and other methods must be employed to estimate the yield stress. One common method is the **offset method**, where a straight line is drawn parallel to the elastic slope and offset an arbitrary amount, most commonly for engineering metals, 0.2%.

The **ultimate strength** or tensile strength is the highest stress the material is capable of withstanding. The point at which the material actually fractures is called the **fracture stress**. For ductile material, ultimate stress is greater than the fracture stress, whereas brittle material, the ultimate stress is equal the fracture stress.

Ductility is the material's ability to stretch or accommodate inelastic deformation without breaking. Another phenomenon that can be observed of a ductile material undergoing tensile testing is **necking**. The

deformation is initially uniform along the length but tends to concentrate in one region as the testing progresses. This can be observed during testing, the cross sectional area of the highest stress region will visibly reduce. Brittle material fail at relatively low values of stain.

In a **static test**, the load is applied slowly and does not affect the behavior of the specimen. In a **dynamic test** the load is applied rapidly or in a cyclical manner, this loading affects the properties of the material.

For more information read Section 1.4 in Mechanics of Materials

Materials:
- Laptop
- Tensile Testing Machine
- 3 samples - choose from sample group A or B

Safety:
Warning: Fracture sounds are loud and sudden. Make sure to have the safety glass on both sides of the testing machine. Wear protective eyeglasses.

Procedure:

1. Power on the provided laptop
2. Connect the materials testing apparatus USB cord to the laptop
3. Ensure that the Materials Testing Machine is secure and clamped to the table.
4. Log on to your CatCourses account and select and open the PASCO capstone file available to you in your resources for this class called "Lab2.cap". A Pasco page with a stress and strain graph should open.
5. Select the green target icon labeled calibration on the toolbar on the far left side of the page. A tab should open asking to select a calibration
6. Select next and you will be given a list of calibration options of which you will select "import calibration from sensor" and then the tap underneath labeled finish
7. Close the calibration tap by selecting the icon once again
8. In the "stress" table, enter in the diameter in the place of "diam" in the equation line.
9. Begin loading the material testing apparatus by unscrewing the top silver cap in between the two rods.
10. Turn the crank clockwise to raise the black load bar far enough up to unscrew and remove the small calibration rod that is screwed into the base where the tensile sample will go.
11. Screw the tensile sample with the base with the shorter side facing downward until the sample is flush with the load cell.
12. Turn the crank counterclockwise to lower the black load bar onto the sample until the sample is all the way through the hole under the load bar.

13. Screw the silver cap removed in step 7 back into its original place on the black load bar and onto the sample
14. Make sure the tensile sample and silver cap are hand tightened securely and **place the safety panels in front and behind the sample with Velcro and make sure they are secure.**
15. Select the icon labeled record in the lower left corner of the PASCO page. You should see the clock below it begin counting.
16. Once you are recording begin very slowly and steadily turning the crank clockwise to put a constant force on the sample. At this point you should begin seeing results on your stress vs. strain graph on the right side of your PASCO page
17. Continue turning the crank at a constant slow speed until the sample fails.
18. Select the record icon again to stop the recording.
19. Save the graph/export the data to excel
20. Repeat steps #7 - 17 for the remaining samples

Exporting to Excel:
1. Select "File" > "Export Data"
2. Save file type as .csv
3. Export
Note: .csv files can be opened by MS Excel.

Data Analysis:
For each material determine the:
- Modulus of Elasticity
- Yield Strength (based on 0.2% offset method) for the metals used
- Ultimate Tensile Strength

Print each graph and mark on them the following:
- Proportional limit
- Yield stress
- Ultimate
- Mark the offset method

Compare to theoretical values

Using Excel, generate two separate stress-strain graphs for each sample. The details for each graph are:
1. Using the data from the extensometer, show the linear portion of the curve to just after the yield point.
2. Using the crossbeam extension data, plot entire response curve from initial loading to failure. In order to calculate strain using the crossbeam extension values, assume an initial length of 10.16cm (4").

On these graphs, label important regions, areas and/or points on the plot that correspond to the data that were calculated. Of course, not all values or properties can be determined from both graphs. Remember to include the appropriate title, axis label and unit information on the graphs.

Important!: The assignment is to create stress-strain diagrams, not force-deformation diagrams. If the y-axis raw data collected is force, it must be converted to stress. Similarly if the x-axis raw data is deformation, it must be converted to strain (use % strain).

Discussion Items for report:
1. Compare experimental values of yield strength, tensile strength, elastic modulus and % elongation with published data for each specimen.
2. Discuss the differences in the shapes of the samples tested. Do they both exhibit the same shape near the yield point?

References:

Gere, J., & Goodno, B. (2013). Mechanics of Materials (8th ed.). Stamford, CT: Cengage Learning.

Instruction Manual: Materials Testing Machine ME-8236 Part of the Comprehensive Materials Testing System ME-8244. (2013). Pasco.

Pre Lab

Stress

Young's Modulus = ————
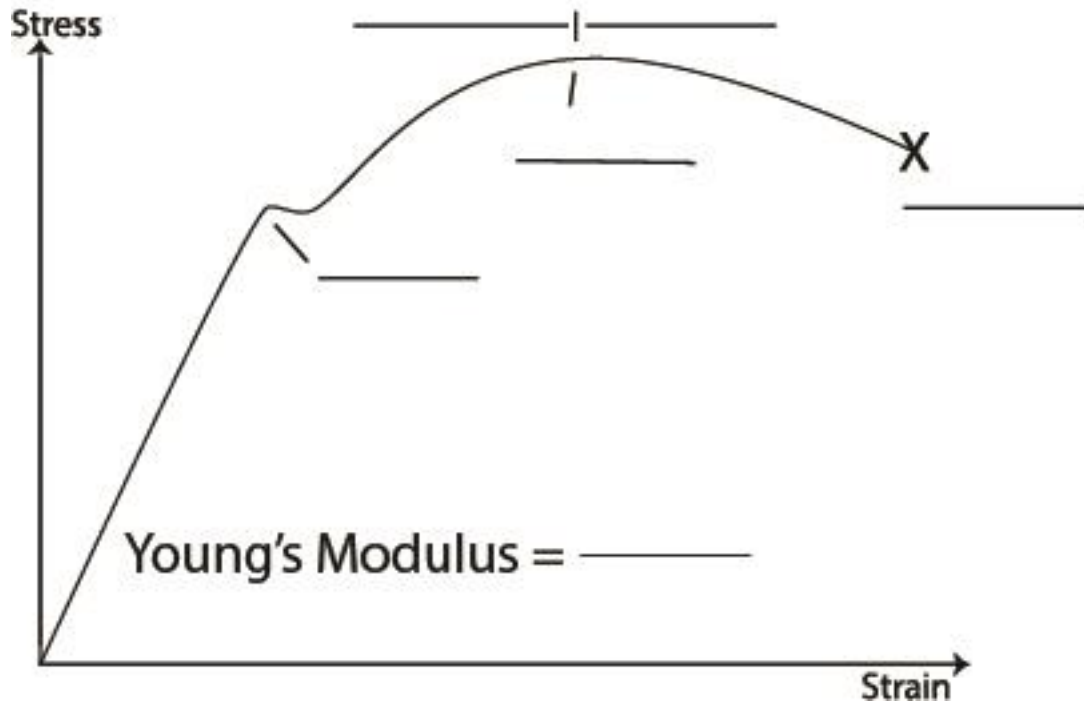
Strain

Identify the different regions of this theoretical stress vs strain graph.

Fill out the table with the theoretical values

Material	Young's Modulus	Yield Strength	Ultimate strength	Fracture Strength
Aluminum, 2024-T3				
Brass, 360				
Annealed steel, C1018				
Cast acrylic (PMMA)				
Polyethylene				
STEEL, C1018				