# MSL Lab Experiment # 3a

# Stress-Strain Behavior of Polymers

A) Reading Materials & Homework:

* Shigley & Mischke, **Mechanical Engineering Design** (6th ed.), attached excerpts.
* **Homework HW3**: A tensile test specimen is made from a polymer sheet with an initial gage length of 50mm and an initial cross-sectional area of 12mm2. The manufacturer lists the Young’s modulus as E=2.6GPa. If the specimen is stretched to an engineering strain of 0.025 by a load producing a 15MPa engineering stress, what is the load on the sample and by what amount has its gage length been increased? What are the true stress and the true strain? Of the true strain at this value of true stress, what portion of it is elastic and thus recovered upon unloading, and what portion of it is plastic? Repeat each of the above steps for a state where an engineering strain of 0.25 is accompanied by an engineering stress of 17MPa.

B) Goals of this Experiment:

1. Use ASTM (American Society for Testing and Materials) standard method to measure tensile properties of polymer materials.

2. Learn how to use Instron machine for tension testing, and LabVIEW software for data acquisition, and graphics display

3. Learn about engineering and true stress-strain diagrams.

4. Determine material properties of a polymer from the stress-strain diagram.

C) Lab Experiment:

The following experiment is designed to conduct the tension testing of polymers and determine yield strength, elongation, ultimate tensile strength, modulus of elasticity, and reduction of area. A tensile specimen of polycarbonate polymer is mounted on the Instron machine with extensometer for this experiment. Your instructor will provide you specific directions on this verbally in class.

1. Measure the cross-sectional area of test specimen and use layout ink to indicate the initial gage length (use 50-mm along the length) on the specimen. This mark can be used to determine elongation after the specimen fractures. Also, gather all the necessary specimen geometry information before mounting specimen in the Instron.
2. Mount specimen in the Instron and attach extensometer along the gage length of specimen. Set the crosshead speed to a value of 4mm/min, and after hitting the Up Arrow allow crosshead motion to continue until failure. Record the crosshead displacement, load, and strain from extensometer using the LABView program throughout the test. *Note:* the maximum strain the extensometer can measure is 50%. Carefully remove the extensometer from the specimen before the 50% tensile strain limit has been reached, without halting crosshead motion, and continue the experiment without the extensometer until it fractures.
3. Obtain data from LabVIEW and import it into Excel. Plot the load-displacement curve. From this, make two plots of the engineering stress-strain curve, one where strain is estimated from the extensometer and another where strain is estimated by the ‘crosshead displacement’ divided by the initial sample gage length. Label axes clearly, including all necessary units. From each of these engineering stress-strain plots, determine the following material properties of the polymer: modulus of elasticity (Young's Modulus), yield strength, ultimate tensile strength, fracture strength. Also quantify the ductility of the material (percent reduction of area and percent total elongation at fracture) by measurements taken from the broken sample.
4. From the properties estimated above, which one has a value which changes the most depending on which engineering stress-strain plot is used? Which of these engineering stress-strain plots do you feel is actually more correct, and in the case of the less correct plot what are the primary sources of error in the strain measurement? Finally, from the more correct engineering stress-strain plot, generate the corresponding true stress-strain curve. Estimate the true strain in the necked region from the area reduction and compare with the average true strain estimated for the gage region at fracture from your true stress-strain curve. Comment on the effect of this discrepancy on your true stress-strain curve.
5. Perform a second tensile test on the polymer, using the following modified protocol. After starting the crosshead motion and sample loading by hitting the Up Arrow console button, halt the test by hitting the Stop button once the extensometer indicates a strain of 2.5%. Then wait 1 minute (watch the load register to see if the sample relaxes during this wait time). Then hit the Down Arrow button unloading the sample until the **load** drops towards zero (do not unload the sample beyond zero as such compression will cause buckling), at which point the Up Arrow button should be hit and the crosshead allowed to move upwards until sample failure. Generate an engineering stress-engineering strain curve from this data, and from it determine the elastic modulus and yield strength demonstrated upon initial loading. Do the values support the repeatability of those found during the first test? Describe the behavior during the wait time. Does the stress drop or stay the same? Describe the unloading behavior observed in terms of elastic and plastic strain.
6. How could the strain be more accurately determined after the material begins to neck, and what additional measurements could have been done during these tensile tests to determine it?

# MSL Lab Experiment # 3b

# Stress-Strain Behavior of Metals

A) Reading Materials & Homework:

* None beyond that already assigned for Lab 3a.

B) Goals of this Experiment:

1. Use ASTM (American Society for Testing and Materials) standard method to measure tensile properties of metallic materials.

2. Learn how to use Instron machine for tension testing, and LabVIEW software for data acquisition, and graphics display

3. Learn about engineering and true stress-strain diagrams.

4. Determine material properties of an aluminum alloy from the stress-strain diagram.

C) Lab Experiment:

The following experiment is designed to conduct tension testing of metallic materials (i.e., aluminum) and determine yield strength, elongation, ultimate tensile strength, modulus of elasticity, and reduction of area. A tensile specimen of aluminum sheet metal is mounted on the Instron machine with extensometer for this experiment.

1. Before mounting the sample for testing, measure the cross-sectional area of the test specimen and indicate the initial gage length (use 50-mm along the length) on the specimen. This mark can be used to make an additional determination of elongation after the specimen fractures. It may be helpful to record these values in an Excel spreadsheet.
2. Mount specimen in the Instron and attach extensometer along the gage length of specimen, carefully following verbal instructions provided in class. Record the crosshead displacement, load, and strain from extensometer using the LABView program. The crosshead speed should be set at 1 mm/min.
3. Obtain data from LabVIEW and import to Excel. Plot load-displacement, and again plot two engineering stress-engineering strain curves using the extensometer as well as the crosshead displacement to estimate strain. Do these curves again differ greatly? In what way? Label axes correctly.
4. Use the engineering stress-engineering strain curve to determine the following material properties of aluminum: modulus of elasticity (Young's modulus), yield strength, ultimate tensile strength, fracture strength. Also quantify the ductility of the material (percent reduction of area and percent total elongation at fracture) by measurements taken from the broken sample. Are either of these ductility measurements particularly difficult for such an Aluminum sample? Describe.
5. Based on the more correct engineering stress-engineering strain curve generated from the tension testing, generate the true stress-true strain curve. For each data point along the true stress-true strain curve, determine the plastic portion *εtp* of the true strain. Assume that the following relationship is valid for the material in the plastic deformation region: *σt* = *o εtpm*where *σ t* is the true stress, *εtp* true plastic strain and *o* and *m* are material constants (strength coefficient and strain hardening exponent). Determine the material constants *o* and *m* from a log-log plot of true stress as a function of true plastic strain. Note: the first few data points at low values of true plastic strain are especially prone to error depending on how well the load and deflection were zeroed prior to the test, and may need to be neglected in order to obtain linear behavior on the log-log plot.
6. Perform a second tensile test on aluminum, using the following modified protocol. After starting the crosshead motion and sample loading by hitting the Up Arrow console button, halt the test by hitting the Stop button once the extensometer indicates a strain of 2.5%. Then wait 1 minute (watch the load register to see if the sample relaxes during this wait time). Then hit the Down Arrow button unloading the sample until the **load** drops to zero, at which point the Up Arrow button should be hit and the crosshead allowed to move upwards until sample failure. Generate an engineering stress-engineering strain curve from this data, and from it determine the elastic modulus and yield strength demonstrated upon initial loading. Do the values support the repeatability of those found during the first test? Describe the behavior during the wait time. Does the stress drop or stay the same? How does the behavior compare to the polycarbonate? Describe the unloading behavior observed in terms of elastic and plastic strain. Upon reloading, did the previously ‘cold-worked’ material demonstrate a higher or lower yield strength than that observed during its initial loading?
7. Plot the engineering stress-engineering strain curves for polycarbonate (from Lab 3a) and aluminum on the same set of axes to be able to compare their properties.

excerprts from pages 256-263, Shigley & Mischke, **Mechanical Engineering Design** (6th ed.).

















