Lab 07: Testing Plastic Tensile Samples

Introduction

The behavior of plastics when deformed in tension is generally like that of metals. We see elastic and plastic deformation, yielding, and strain hardening, but the differences are notable. Often we might not see a linear-elastic behavior at the start of the test and so Young's Modulus would not represent the plastic's stiffness. Yielding is defined differently and it may coincide with the tensile strength. Plastics also tend to be more sensitive to the strain rate than metals and this has to be considered when conducting the test and when reporting the results.

In this lab you will tensile test two types of plastic, and measure the stiffness of the materials using several different methods.

Equipment

Qty	Items	Part #
1	Materials Testing Apparatus	ME-8236
2	Tensile Sample (Acrylic)	ME-8234
1	Tensile Sample (Polyethylene)	ME-8235
1	Calipers	SE-8710

Written by Jon Hanks

Figure 1. Testing Plastic Tensile Samples

Behavior of Plastics in Tension

When a plastic sample is loaded in tension it will elongate. If pulled far enough it will fail, breaking into two pieces. Between the point where it was initially loaded and it failed, it will generally exhibit the following types of behavior, as shown in Figure 2.

Elastic Deformation – This deformation is temporary and is recovered as soon as the load is removed. The sample returns to its original size. Depending on the type of plastic, some time-dependent elastic and plastic deformation (anelasticity and creep) may accompany the initial elastic deformation of the specimen.

Yielding – This marks the end of the initial elastic region and the start of plastic deformation and in some cases the onset of necking.

Strain Softening – Following yielding some materials will appear to soften (load decreases) as a neck forms (see Fig. 3) and the structure begins the transformation from one of randomly oriented chains and crystallites into a more aligned structure.

Cold Drawing – The crystallites are rotating and being reoriented. Most of this is happening in the zone where the neck is forming.

Strain Hardening – Once the specimen's structure is fully drawn the stress increases again. This new structure is now resisting deformation.

Fracture – The specimen finally breaks.

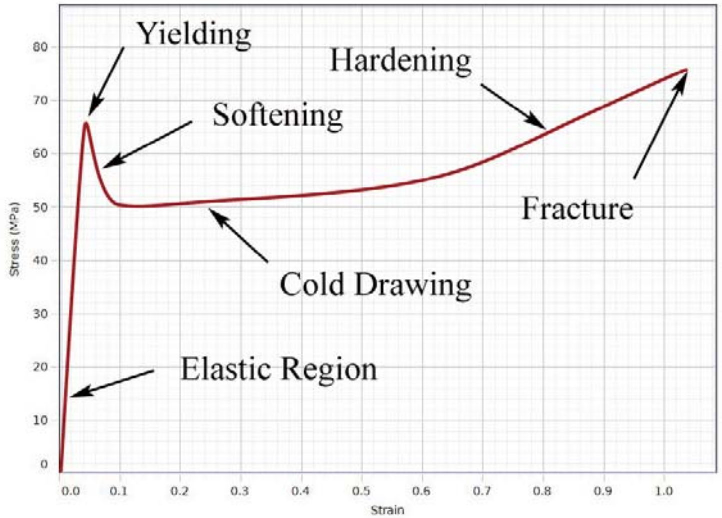


Figure 2: Typical stress-strain curve for plastic.

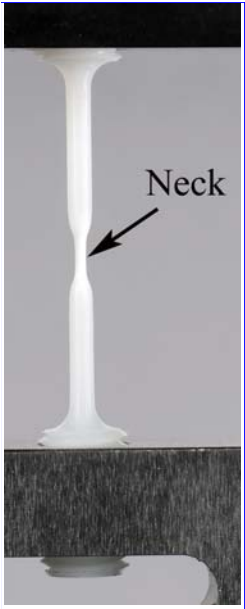


Figure 3. Necking

Setup

1. Use calipers (or a micrometer) to measure the diameter of the machined portion of the tensile sample. Edit the value for diameter in line #2 of the calculator.

2. Note that the calculator also has a value for the length of the sample. If you measure the complete machined portion, you should get about 38 mm. However, since there is a radius, the length of the thinner part that is actually stretching, is less. A good average value to use for the length is 35 ± 1 mm.

"Seating" the Test Sample and Setting Pre-Load

Note: The following is written for using a test sample (see Figure 1), but you should also use this method when performing a compliance calibration of the Materials Tester using the Calibration Rod. In the following procedure, you will load the system to introduce a small pre-load.

1. Install the acrylic test sample as shown in Figure 1. Make sure that the knurled cap is loose, not creating a force on the load cell.

2. Click on Record. Tighten the knurled cap. Note that the digits display shows the force on the load cell.

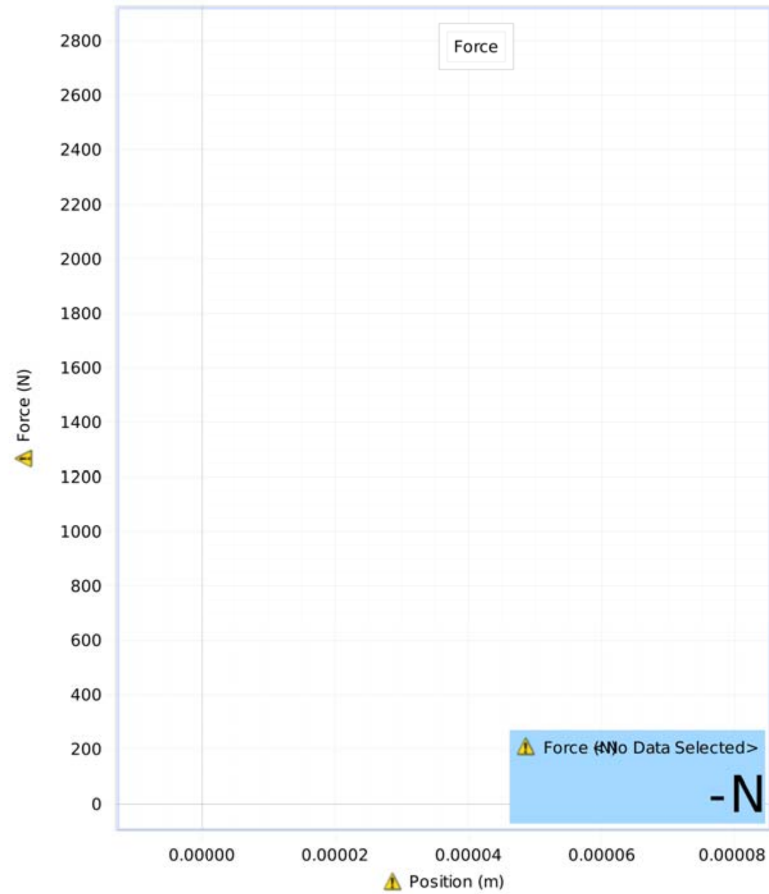
3. Slowly turn the crank clockwise, increasing the force to about 10 N. Note that the position and force data are being plotted on the graph.

4. Click on Stop, and do NOT change the crank position. Since the sensor will auto-zero the next time you start recording data, this puts a 10 N pre-load on the sample which results in better data. You should use this same method when performing any compliance calibration of the Material Tester.

7. You can use the Delete Run menu (Controls tool bar, below) to delete your practice runs. Proceed to the next page to collect your actual data runs.

Note: You can use the Calibration routine (in the Tools Palette at left) to perform a compliance calibration at any time. You should calibrate the Materials Tester over the same range you expect to use in testing samples. In this lab, for example, a max range of 1000 N is sufficient. When you store your calibration, create a name that includes the max force used, and record that value in the lab as well.

Compliance calibration called "Calibration 1000" was over a range of 1000 N and used a pre-load of 10 N.



Test Runs: Seating the Sample

Breaking the Sample

1. You will deform the acrylic tensile sample, pulling it apart until it breaks. Try to turn the crank at a steady rate of about 20 to 30 mm/Min. Make sure the safety shield is in place.

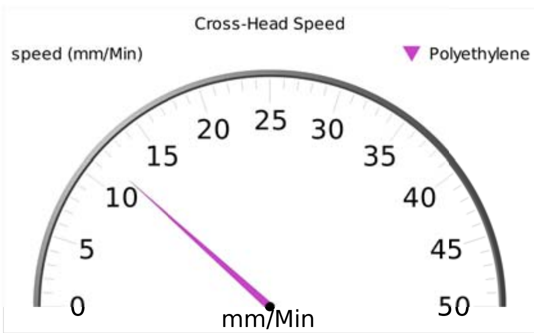
2. Click on Record. Turn the crank clockwise, stretching the sample. Continue cranking until the sample breaks. Click on Stop.

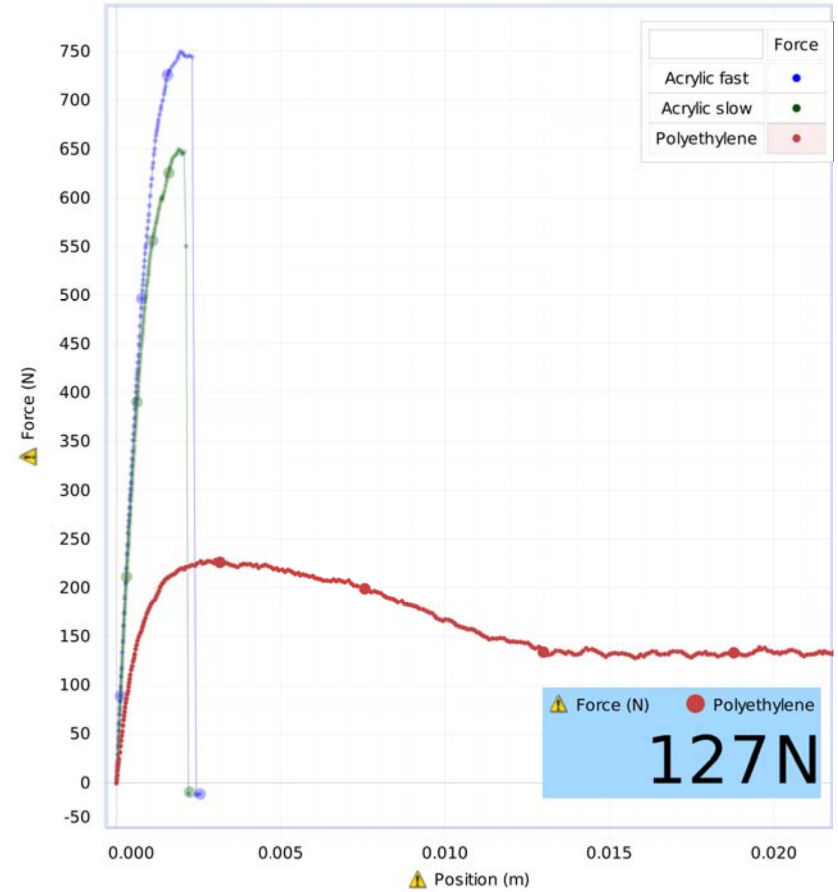
3. Replace the broken sample with your second acrylic sample. Repeat the steps from the previous page to properly seat the sample.

4. For this run, turn the crank very slowly, less than 5 mm/Min. Click on Record. Turn the crank until the sample breaks. Click on Stop.

5. Repeat using the polyethylene sample. This material will stretch a **long** way, so it is best to use a fast rate. Continue cranking at least until the necked region that forms is 2 cm long. You probably will not be able to break the sample.

6. Rename your runs Acrylic fast, Acrylic slow, and Polyethylene.





Tensile Test of Sample

Linear Elastic Behavior

For plastics that exhibit linear-elastic behavior, **Young's Modulus** (E) is the property that describes the stiffness of the material. It is measured as the slope of the linear portion of the stress-strain curve.

1. Confirm that the equations for Stress and Strain in the calculator are being done correctly.

2. For your two **acrylic** samples, Measure the slope in the linear portion of the graph to find Young's Modulus for the material. What is the uncertainty in your measurements?

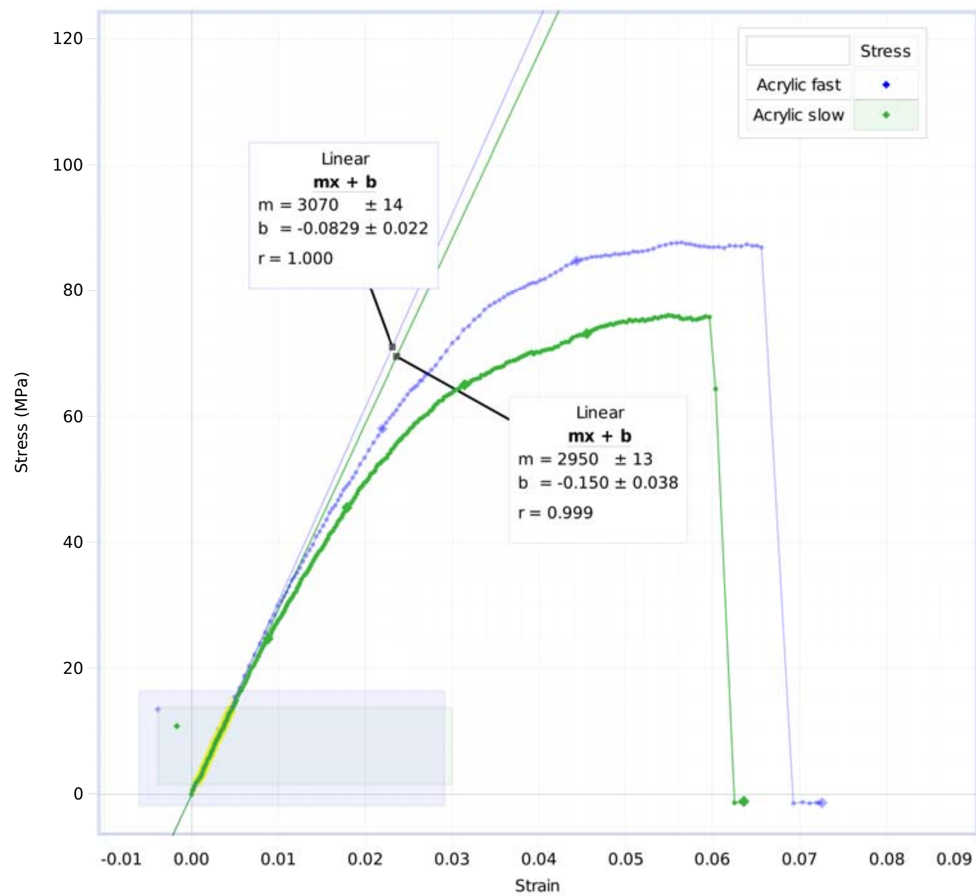
3. How do the two values compare? What effect did the strain rate have on the modulus and on the tensile strength?

4. How do your values compare to those listed in reference data tables for the material?

Answers.

slope = E = 3,000 MPa = 3 ± .5 GPa
uncertainty based on slope in different regions, and uncertainty in sample length

Faster rate gives higher slope, higher Tensile Strength, and more linear elastic region.



Finding Slope

Nonlinear Elastic Behavior

For plastics that do **not** exhibit linear-elastic behavior, the following moduli can be used to describe the stiffness of the material:

Initial Modulus – slope of the stress-strain curve at the very start of the test.

Secant Modulus – slope in the stress-strain curve from the origin to a specified strain.

Tangent Modulus – slope in the stress-strain curve at a specified strain: For example, 2% of strain can be used.

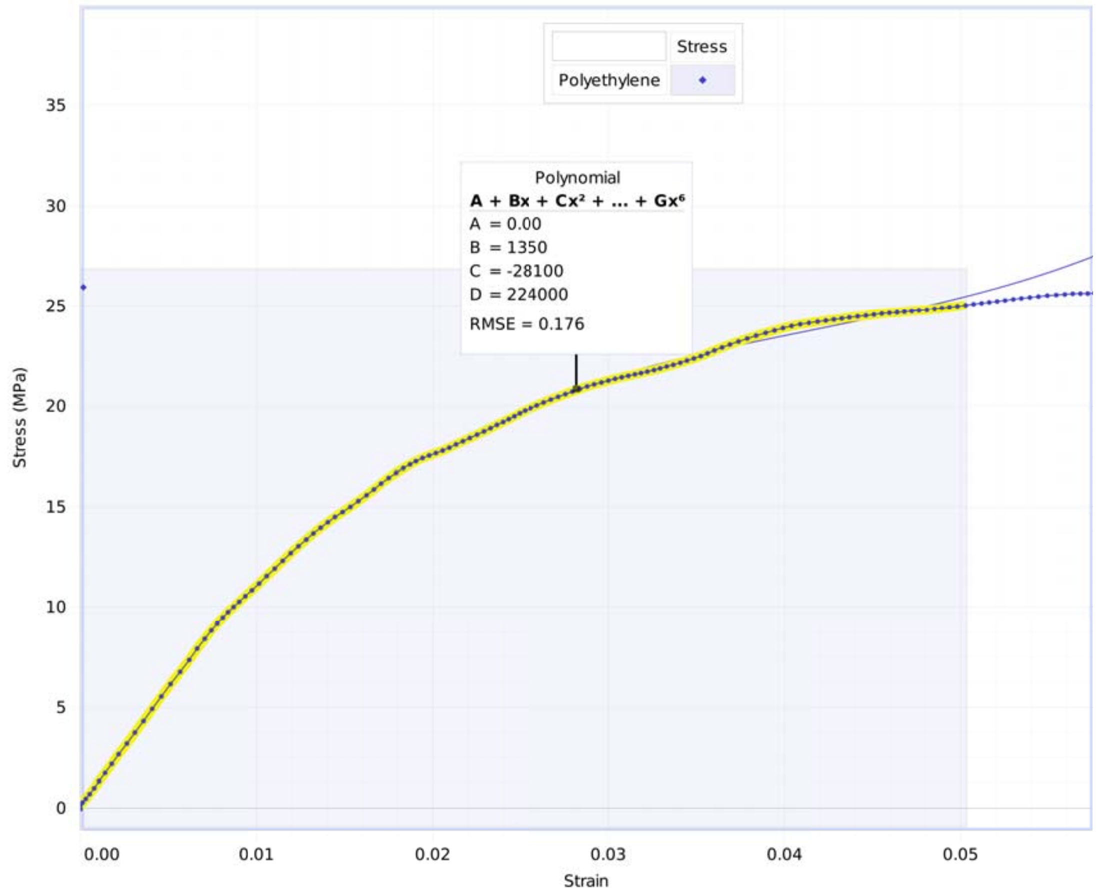
Chord Modulus – slope in the stress-strain curve measured between two specified strains.

Since the actual data tends to be fairly noisy, the general approach is to fit a polynomial curve to the data, and then make all measurements from that fit.

1. Use the highlighter to select only the data up to about 5% strain.

2. Fit a 4 term polynomial to your polyethylene test sample data. Use the Curve Fit Editor in the Tools Palette at left. You can change the number of terms, and lock A=0.

3. Open the Calculator window and edit the coefficients for the poly fit. On the next page, you will make all your measurements on this curve fit model, not on your actual data.



Finding Slope

4. Your curve fit model should show on the graph. The scale is locked to only show the curve up to 5% strain.

5. Use the Slope tool to measure Initial Modulus.

6. Use the Slope tool to measure Tangent Modulus at 2% strain

7. Use rise over run to measure the Secant Modulus at 2% strain

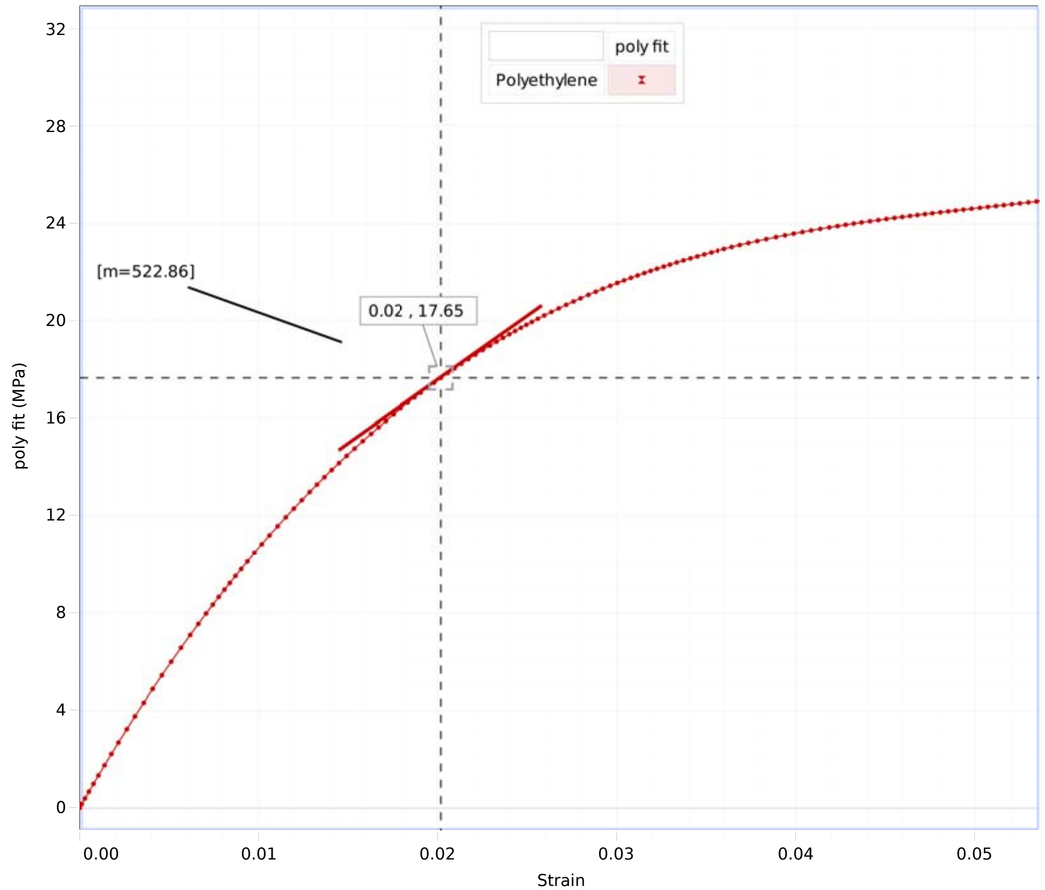
8. How do your values compare to those listed in reference data tables for the material?

Initial Modulus = 1.3 GPa

Tangent Modulus = 0.5 GPa

Secant Modulus=0.9 GPa

Polyethylene has a Young's Modulus of about 1 GPa.



Finding Slope

9. Measure and record the Tensile Strength of the polyethylene material. Compare your value to those listed in reference data tables for the material. Compare the value found for this material to other materials tested.

10. Use Text annotations to mark the following regions of your polyethylene graph: Yielding, Softening, Cold Drawing, Necking

11. What are the differences in the two plastics?

Tensile Strength = 25 MPa
Data Table Values = 20 - 50 MPa

The acrylic is more brittle and breaks at the tensile strength. The polyethylene is much more ductile, and exhibits the softening and cold drawing properties while "necking".

The tensile tester can not stretch the polyethylene sample far enough to break it.