

Tensile Testing Plastic Coupons

Equipment

Qty	Description	Part Number
1	Materials Testing Apparatus	ME-8236
1	Plastic Test Coupons	AP-8222
1	Material Coupon Adapter	ME-8238
1	Calipers	SE-8710

Introduction

The ME-8238 Coupon Adapter allows you to tensile test the AP-8222 Plastic Coupons, which includes four different types of plastics. In this lab you will measure the stiffness of the materials using several different methods, in addition to determining the tensile strength. Plastics tested are ABS, Nylon, Polypropylene (PP) and High-Impact Polystyrene (HIPS).

Theory

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. 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 must be considered when conducting the test and when reporting the results.

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.

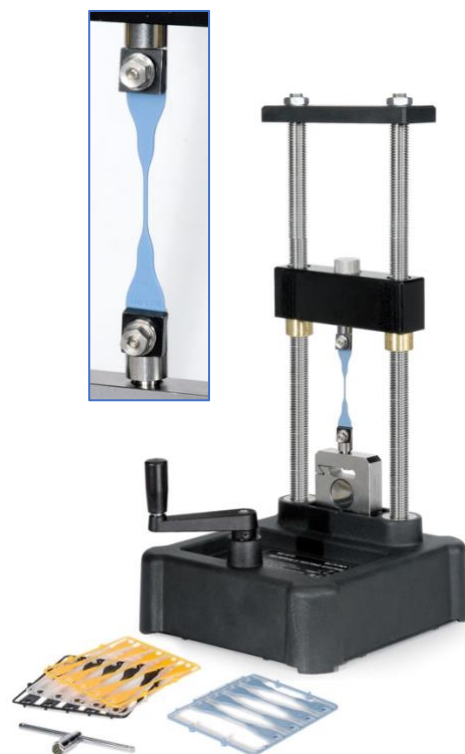


Figure 1: Testing Plastic Coupons

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.

Setup

Note: Installing the Coupon Adapter

Notice that the two parts of the Coupon Adapter are NOT identical. The one with the shorter threads goes on the bottom, and screws directly into the load cell as shown in Figure 1. Screw it most of the way in, but you want the clamp assembly to face forward so that you can use the wrench. The other adapter, with the longer threads, sticks up through the cross-head and is held by the knurled cap nut.

1. Connect the Materials Testing Machine to a PASPORT interface or AirLink. In the PASCO Capstone calculator, create the following calculations, add your values for the constants as you determine their values:

$$\text{Stress} = 10^{-9} * [\text{Force (N)}] / (\pi * (\text{Dia}/2)^2)$$

$$\text{Dia} =$$

$$\text{Strain} = [\text{Position (m)}] / L$$

$$L =$$

$$\text{speed} = 60000 * \text{derivative}(2, [\text{Position (m)}], [\text{Time (s)}])$$

$$\text{poly fit} = A + B * [\text{Strain}] + C * [\text{Strain}]^2 + D * [\text{Strain}]^3$$

$$A = 0$$

$$B = 1$$

$$C = 1$$

$$D = 1$$

with units of MPa

with units of m

unitless

with units of mm

mm/Min

MPa

MPa

MPa

MPa

MPa

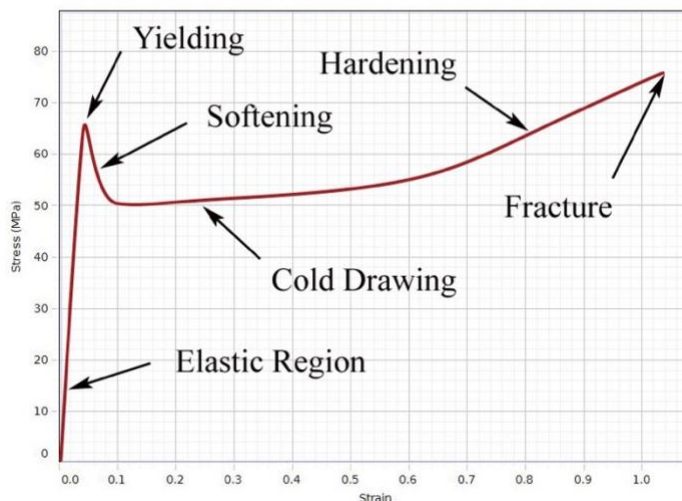


Figure 2: Typical stress-strain curve for plastic

2. Use calipers (or a micrometer) to measure the diameter of the thin round portion of the coupons. Edit the value for diameter in line #2 of the calculator.

3. Note that the calculator also has a value for the length of the sample. If you measure the thin, round portion, you should get about 20 mm. However, since there is a taper, the length that is actually stretching is longer. A good average value to use for the length is 22 ± 2 mm.

4. There is a ridge on one side of the coupon that fits under the black clamp on the adapter, as shown in Figure 3.

5. Use the socket wrench to tighten the hex nuts, as shown in Figure 4.

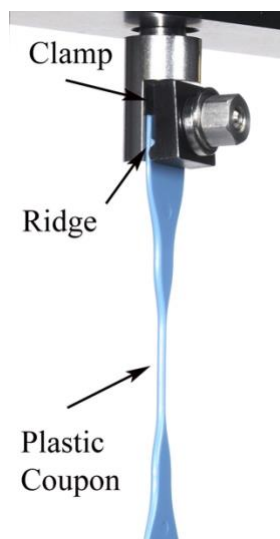


Figure 3: Installing Coupons



Figure 4: Tighten hex nuts

6. 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, the max force is under 200 N, and the compliance calibration is not really even needed. Note that one of the choices in the calibration is to just use "RawValues" with no corrections. As always, keep a record of what you used.
7. In PASCO Capstone, create a Meter display of Speed, a Graph display of Force vs. Position, a Digits display of Force, and a Graph display of Stress vs. Strain.
8. Set the sample rate to 20 Hz.

Procedure: Breaking the Sample

1. You will deform the coupon, pulling it apart until it breaks. Try to turn the crank at a steady rate of about 20 to 30 mm/Min.
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 another coupon and repeat.
4. Repeat for the other coupons.
5. Rename your runs to indicate the material used.

Analysis: Linear Elastic Behavior

1. 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.
2. Confirm that the equations for Stress and Strain in the calculator are being done correctly.
3. For your ABS sample, measure the slope in the linear portion of the graph to find Young's Modulus for the material. What is the uncertainty in your measurement?
4. How does your value compare to that listed in reference data tables for the material?

Analysis: Nonlinear Elastic Behavior

1. For plastics that do **not** exhibit linear-elastic behavior, the following moduli can be used to describe the stiffness of the material: **Initial Modulus** is the slope of the stress-strain curve at the very start of the test. **Secant Modulus** is the slope in the stress-strain curve from the origin to a specified strain. **Tangent Modulus** is slope in the stress-strain curve at a specified strain: For example, 2% of strain can be used. **Chord Modulus** is the 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.
2. For your nylon data, use the highlighter to select only the data up to about 5% strain.
3. Fit a 4-term polynomial to your nylon test sample data. Use the Curve Fit Editor in the Tools Palette. You can change the number of terms, and lock $A = 0$.
4. Open the Calculator window and edit the coefficients for the poly fit. You will make your remaining measurements on this curve fit model, not on your actual data.
5. In PASCO Capstone, create a graph display of Poly fit vs. Strain.
6. Lock the scale to only show the curve up to 5% strain.
7. Use the Slope tool to measure Initial Modulus.
8. Use the Slope tool to measure Tangent Modulus at 2% strain.
9. Use rise over run to measure the Secant Modulus at 2% strain.
10. How do your values compare to those listed in reference data tables for the material?
11. Measure and record the "stiffness" of the other two plastics. List the method you used and compare to values listed in reference data tables.

12. The Tensile Strength is the maximum stress on the graph. Measure and record this quantity for each sample. You should also note if this occurs at yield or at fracture.
13. Compare your measurement to values listed in reference data tables.

Analysis: Material Comparison

1. Which material has a stress-strain graph that most closely resembles the "typical" curve for plastics shown in the theory section of this lab.
2. For that data, use the Text Annotations to mark the following regions of your graph: Elastic, Yielding, Softening, Hardening, Cold Drawing, and Necking.
3. What are the major differences in the four plastics tested?