# ME305: Mechanics of Materials

# TENSION LAB

**(Revised by Luke Colby, Kris Pelletier, Prof. Isaacson, and Prof. Barbone Summer 2002; Bridget Reardon Spring 2009; Mogensen Fall 2013)**

## OBJECTIVES:

1. To conduct uniaxial tension testing of various materials.
2. To observe tensile deformation and failure.
3. To construct and interpret stress/strain curves.

## PRELAB QUESTIONS:

(To be submitted prior to performing the experiment.)

1. Draw a typical stress/strain curve for steel. Label the following features: yield stress, plastic region, elastic modulus, ultimate stress, and strain hardening.
2. List the elastic moduli and yield strengths for C1045 Steel, 7075-T6 Aluminum, Copper, and Acrylic.
3. Based on ASTM standard E8, what material properties can be determined from a tension test of metallic materials? (ASTM Standard E8 is on reserve in SCI/ENG Library under course ME 305)

## BACKGROUND:

Tensile Test:

The strength of a material depends on its ability to sustain a load without undue deformation or failure. This property is inherent in the material itself, and must be determined by experiment. As a result, several types of tests have been developed to evaluate a material's strength under loads that are static, cyclic, extended in duration, or impulsive. One of the most important tests to perform is the static tensile test. Although many important mechanical properties of a material can be determined from this test, it is used primarily to determine the relationship between the average normal stress and normal strain in many engineering materials such as metals, ceramics, polymers, and composites.

To perform this test, a specimen of the material is made into a standard shape and size. Measurements are taken of both the specimens initial cross sectional area, $A_0$, and the gauge length distance, $L_0$. A testing machine is then used to stretch the specimen at a very slow, constant rate until it reaches the breaking point. At frequent intervals during the test, data is recorded of the applied load, P, and the change in gauge length of the specimen, $\Delta L$. For U.S. applications, standard specimen dimensions and testing conditions are set by the American Society for Testing and Material (ASTM), and are contained in the Standard ASTM E8.

Stress-Strain Diagram:

From the data obtained during the tensile test, it is possible to compute the values of stress and strain, and plot the results. The resulting curve is called the stress-strain diagram.

Using the recorded data, and the fact that the only load on the specimen is a pure tensile load, the nominal, or engineering, normal tensile stress, σ, can be determined by dividing the applied load, P, by the specimen's original cross sectional area, $A_0$.

$$\sigma = \frac{P}{A_o} \quad (1)$$

Likewise, the nominal, or engineering, strain is found by dividing the change in the specimen's gauge length, ΔL, by the specimen's original gauge length, $L_0$. Here the strain, ε, is assumed to be constant along the gauge length. Therefore:

$$\varepsilon = \frac{\Delta L}{L_o} \quad (2)$$

If the corresponding values of stress and strain are plotted as a graph, for which the ordinate (y-axis) is the stress, and the abscissa (x-axis) is the strain, the resulting curve is called a conventional stress-strain diagram. The diagram is very important in engineering since it provides the means for obtaining data about a material's strength without regard for the materials physical size or shape.

0.2% Offset Method

With some materials, the yield point is easily defined on the stress-strain curve. For some materials however, the yield point is not as discernable, but still exhibit large strain deformation following the linear elastic phase. In such cases, the 0.2% offset method is applied to define the yield stress of the material. A line is drawn parallel to the linear elastic region of the stress-strain curve, but offset by 0.002 strain (or 0.2% strain). The intersection of the parallel line with the stress-strain curve is known as the 0.2% offset yield stress. This allows for consistency in reporting the yield stress of materials. For U.S. applications this standard testing method is contained in the Standard ASTM E8.

**PROCEDURE:**

An Instron universal testing machine is used for this experiment. The system is hydraulically operated with computer control and data acquisition. **Please follow the safety instructions of the teaching fellow and wear safety glasses at all times while the machine is in use.**

The Teaching Fellow will perform the lab by following the TF Lab procedure, but he/she may ask you to help with various components of the lab. During the lab pay close attention to what the TF does because you will be required to write up an outline of the procedure in your report. Below is a summary of what you will be doing.

Prior to starting the testing process you will:

- Verify that the Instron load cell and extensometers are calibrated.
- Specify material of each sample; inspect each sample for damage; measure and record sample dimensions ($A_0$, $L_0$).
- Calculate the theoretical applied force for each sample at the yield load and ultimate load.

For each sample to be tested:

- Load specimen in machine.
- Attach extensometer. Note: The extensometer gauge length is 80mm.
- Prepare load ramp in computer controller.
- Prepare data acquisition.
- Run test.
- Remove specimen.
- Inspect and record shape of fracture surface of specimen.

Force and displacement data for each specimen will be available to you after the lab in electronic format. Also, the TF should show you a sample data analysis in lab. If that is not done, please remind the TF to do it.

**ANALYSIS:**

1. Using the data collected, construct complete stress-strain curves for each sample. The resulting plots should contain a title, axis labels, and appropriate scales and units. NOTE: The Instron Data Acquisition program will output a CSV format file, open with Excel (or similar) software and you will see following data columns: "Total Time (s)", "Cycle Elapsed Time (s)," "Total Cycles," "Elapsed Cycles," "Step," "Total Cycle Count(8800 (0,3) Waveform)," "Position(8800 (0,3):Position) (mm)," "Load(8800 (0,3):Load) (kN)," and "Extension mm from Extensometer (mm)." The relevant data for the calculation of the stress-strain curve is in the last two columns. "Load(8800 (0,3):Load) (kN)" is the force output from the Instron and used to calculate stress; this is the P (kN) in your stress equation (1). Note the typical units for stress are MPa. "Extension mm from Extensometer (mm)" is the distance (mm) output from the extensometer; this is $\Delta L$ in your strain equation (2).

2. Determine the elastic modulus for each of the samples. Determine graphically by finding the slope of the stress-strain curve in the linear region of the curve. The best way to do this in Excel is simply to fit a trend line to the set of data points in the linear region and take the slope of the line of best fit as the elastic modulus. Note: Be sure you are only fitting data in the linear region and take care that your units work out and that you are getting values of E for the metals in the Giga-Pascal range, (10^9). Each specimen should have a separate graph showing only the linear region and enough of the non-linear region so that analysis parts 2 and 3 can be analyzed on the same graph.

3. Determine the yield strength for all the samples using the 0.2% strain offset method. This should appear on the plot and be labeled. (Hint: Zoom in on the elastic region of the stress-strain curve so that the linear region and just the beginning of the plastic region fill your entire graph. Draw a line parallel to your trend line of analysis part 2, offset in the strain coordinate by 0.2%, and find out where it intersects the curve. The best way to do this in Excel is simply to plot a couple of points from the trend line you created in question 2 and add 0.2% to the x coordinate. Then just add a trend line to these data points and see where it intersects the data. Note: If you plotted using percent strain then you should be adding 0.2, but if you divided everything by 100 and plotted actual strain, not expressed as a percent, then you should be adding 0.002). Remember a separate graph should be used for each specimen for steps two and three.

4. On a single graph plot the stress strain values for all the samples tested. Be sure to label each curve clearly so that you can see the differences in the shapes of the curves from sample to sample. Look at the different curves for the various steel and aluminum alloys and comment on the differences in their properties. Also, using your book or www.matweb.com compare the densities of the materials and comment on how the combination of weight and tensile strength change from sample to sample and the tradeoffs that come with them. In a couple of sentences discuss these differences and how they might affect which material chosen by an engineer designing an aerospace or mechanical system.

5. Construct a table that includes yield stress, ultimate stress, and elastic modulus as interpreted from the stress-strain plots. Compare (% error) these values to known values of the materials. Values needed that are not in your textbook can be found on www.matweb.com.

**QUESTIONS:**

(The answers to these questions are to be submitted along with the lab report.)

1. Discuss possible sources of error between measured and tabulated material properties.

2. Discuss the similarities and differences between the measured stress-strain curve for steel and the stress-strain curve constructed in the pre-lab. What explanation can you give for the differences?

3. Describe the features of the fracture surface observed for different materials tested.