ME 354 MECHANICS OF MATERIALS LABORATORY

# MECHANICAL PROPERTIES AND PERFORMANCE OF MATERIALS: TENSILE TESTING

## PURPOSE

The purpose of this exercise is to obtain a number of experimental results important for the characterization of the mechanical properties and performance of materials. The tensile test is a fundamental mechanical test for material properties that are used in engineering design, analysis of structures, and materials development.

## EQUIPMENT

• Reduced gage section tensile test specimens of 6061-T6 aluminum
• Reduced gage section tensile test specimens of 1018 cold rolled steel
• Reduced gage section tensile test specimens of polymethymethacrylate (cast acrylic))
• Reduced gage section tensile test specimens of polycarbonate
• Clip-on axial and transverse extensometers
• Tensile test machine with grips, controller, and data acquisition system

## PROCEDURE

**Setup the Instron Load Frame:**
• Initiate the BlueHill data acquisition and control program and set-up the parameters for the test.
• Measure the diameter of the gage section for each test specimen to within 0.02 mm.
• Ensure the force output is zeroed (balance).
• Install the one end of the tensile test specimen in the top grip of the test machine.
• Install the other end of the tensile test specimen in the lower grip of the test machine.
• Zero the actuator position of the test machine.
• Attach the axial and transverse extensometers to the gage section of the test specimen, centering them in the gage section.
• Zero the output from the strain conditioners.
• Record the length of the gage section defined by the extensometer.

**Perform the Tensile Test:**
• Initiate the test sequence via the computer program.
• A warning message will prompt to remove the extensometers at some pre-set strain before failure to avoid damage to the extensometers.
• The test will continue until the test specimen fractures.
• Measure the smallest diameter of the gage section at the location of failure for the specimens on display.
• Save a copy of the data file in Excel format. *The excel file will be distributed to you via the class website*

# LAB REPORT

Prepare a "Formal Lab Report" describing your work, following the guidelines described on the class website. Include the following in your formal lab report:

- Plots of engineering stress (MPa) versus engineering strain (use %, m/m or $\varepsilon_\mu$) for each material showing **all** of the tensile test data for each material (there were three specimens of each material tested). For strain, use the data in the column labeled "tensile strain." You should have a total of four plots that look professional.

- Determine from the data the ultimate tensile strength $\sigma_u$ **for each material**. Report the average and standard deviation for each material with appropriate units.

- Determine from the data the modulus of elasticity *E* and yield stress $\sigma_0$ **for steel and aluminum**. Find *E* using a least-squares approach with the elastic portion of the data. Report the average and standard deviation for the material with appropriate units

- Determine the modulus of resilience and modulus of toughness from one test data set **for each material**. Describe what computational method or approach you used, e.g. Matlab's 'trapz' function.

- From the final length and diameter measurements, determine the true fracture strength, $\tilde{\sigma}_f = P_f / A_f$, percent reduction in area, $\%RA = 100\left(A_0 - A_f / A_0\right)$, and percent elongation, $\%el = 100\left(L_f - L_0 / L_0\right)$, **for each material**.

- Plot the true stress versus true strain curve ($\tilde{\sigma}$ vs. $\tilde{\varepsilon}$) the engineering stress versus engineering strain ($\sigma$ vs. $\varepsilon$) on the same graph for **one representative data set of aluminum**. Determine the true stress and true strain at maximum load (i.e. prior to the onset of necking).

- Plot the logarithm of true stress versus the logarithm of true plastic strain (log $\tilde{\sigma}$ vs. log $\tilde{\varepsilon}_p$) **for one data set of aluminum**. Confine the range to values greater than *three* times the yield strain and less than the ultimate strain. Determine the 'best' values of *n* and *H* using a least-squares fit for the approximate constitutive relation:

$$\tilde{\sigma} = H \tilde{\varepsilon}_p^{\,n} \qquad (1)$$

where $\tilde{\sigma}$ is the true stress, $\tilde{\varepsilon}_p$ is the true plastic strain, *H* is the strength coefficient, *n* is the strain hardening exponent per ASTM E646. Add a plot of Eq. 1 to the figures. Determine the percent error between the true stress calculated from the approximate constitutive relation and the measured true stress at measured true strain values of 0.1%, 1%, and 5%.

REFERENCES

Annual Book of ASTM Standards, American Society for Testing and Materials, Vol. 3.01
E8 and E8M [Metric version] Standard Test Methods of Tension Testing of Metallic Materials
E646 Standard Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials