

## **LAB #1: UNIAXIAL TENSION TEST ASSIGNMENT (Distance Education Version)**

**1. Purpose.** The purpose of this lab is to conduct a Uniaxial Tension Test (UTT) on three different materials—A36 Steel, 6061-T6 Aluminum, and Gray Cast Iron—to construct the corresponding  $\sigma$ - $\epsilon$  diagrams and to evaluate and compare their material properties. In the standard version of CE300, this is a hands-on experience, in which cadets have an opportunity to gain a better appreciation for the physical phenomena associated with load, deformation, stress, and strain—in addition to the conceptual and computational aspects of these concepts. Obviously, in our “distance education” format, you will miss the hands-on aspect of the exercise; nonetheless, you will still have an opportunity to work with real-world experimental data and to see how these data can be processed and analyzed in order to gain a better understanding of the properties of various materials.

**2. Conduct of the Lab.** During the UTT, three different specimens are subjected to progressively increasing centric axial tension. Load and elongation are measured at specified intervals during the test and are then recorded in an Excel spreadsheet.

In the CE300 Distance Education Course, you are provided with the following materials as a substitute for the conduct of the actual hands-on laboratory experiment:

- A PowerPoint slide show to familiarize you with the laboratory equipment used to run the test. (You viewed this presentation in Lesson 11.)
- A detailed description of the test procedures, *for your background information only*.
- An Excel spreadsheet containing all of the raw load and deformation data for the three materials—A36 Steel, 6061-T6 Aluminum, and Gray Cast Iron.

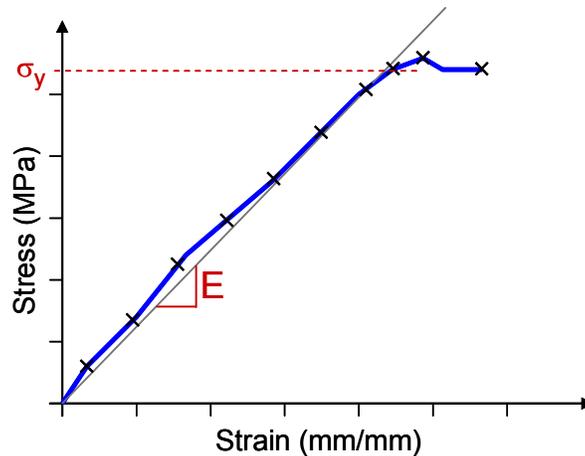
**3. Analysis of the Data.** To process and analyze your experimental data, you should do the following:

a. For each material, calculate the *average* diameter of the specimen. Then use this average diameter to calculate the cross-sectional area, and record it on the data sheet.

b. For each material, calculate the fracture strain,  $\epsilon_f$ , using the Initial Length,  $L_o$ , and the Fracture Length recorded on the data sheet.

c. Create another Excel spreadsheet that (1) converts all experimental values of *load* (in kN) to *stress* (in MPa); (2) converts all experimental values of *deformation* (in mm) to *strain* (in mm/mm); and (3) generates two different stress-strain graphs for each material (see below). Be careful with your unit conversions!

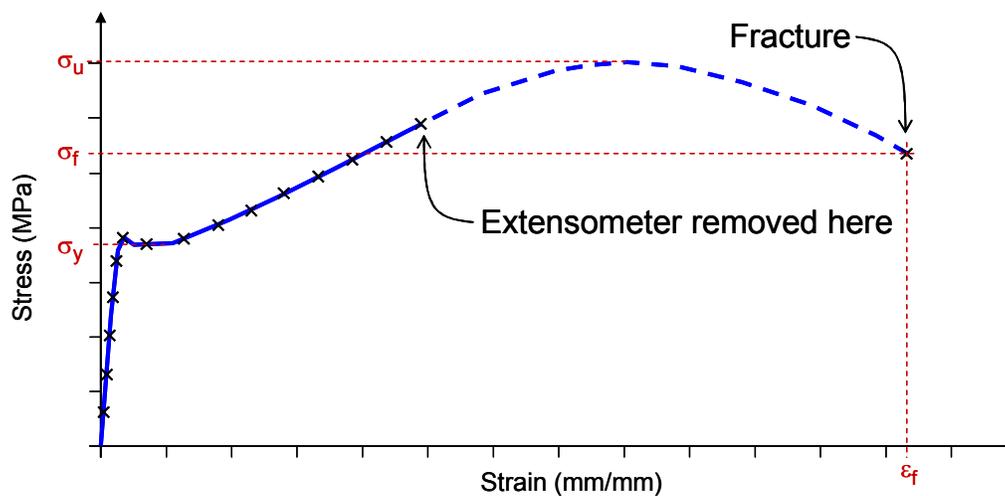
(1) The first stress-strain graph should include *only* those data points corresponding to the elastic region, up to and including the yield point. Because it is focused on the elastic region, this graph is useful for determining the Modulus of Elasticity,  $E$ , and the Yield Stress,  $\sigma_y$ . Annotate these *values* directly on the graph, by using the drawing tools in Excel or, if you prefer, by printing out a hard copy of the graph and then annotating it by hand with a pencil or pen. The result should look (approximately) like the sketch below.



On this graph, note the following:

- The point (0,0) is a valid data point, even though it was not contained on the data sheet, because zero load does, in fact, result in zero deformation.
- All of your data points to the right of the yield point are omitted from this graph.
- The Modulus of Elasticity is the slope of a “best fit” straight line, fitted to *only* the elastic portion of the stress-strain curve. You can do this with Excel’s Linear Regression function, as long as you are careful to fit the regression line to only the elastic data points. As an alternative, you can just sketch in a “best fit” line and calculate its slope manually.
- If the stress-strain curve has no clear yield point, use the 0.2% Offset Method to find the yield stress.

(2) The second stress-strain graph should include the full range of stress-strain data from zero through fracture. On this graph, annotate the Yield Stress,  $\sigma_y$ , the Ultimate Stress,  $\sigma_u$ , the Fracture Stress,  $\sigma_f$ , and the Fracture Strain,  $\epsilon_f$ . The result should look (approximately) like the sketch below.



On this graph, note the following:

- Because we had to remove the extensometer prior to the completion of the test (to prevent damage to the instrument when the material fractures), you do not have enough measured

data to plot the entire stress-strain curve. Nonetheless, you should sketch in the remainder of the curve, based on three pieces of additional data: (1) During the test, the ultimate load is read from the load meter and recorded on the data sheet; this should be converted to  $\sigma_u$  to determine the overall height of the curve. (2) During the test, the load at fracture is read from the load meter and recorded on the data sheet; this should be converted to  $\sigma_f$  and used to plot the final data point on the curve. (3) After the conclusion of the test, the length of the fractured specimen is measured. This should be used to calculate  $\epsilon_f$  and used to determine the final data point on the curve. Note that the sketched portion of the stress-strain curve is shown in dotted lines in the picture above.

- When the full range of strain values is plotted, the elastic portion of the curve is typically compressed into a narrow region on the left-hand side of the curve. This is why you *should not* use this graph to calculate the Modulus of Elasticity.

d. Once all six stress-strain curves (two each for the three materials) are plotted, you will be able to use these graphs as the basis for comparing the mechanical properties of the three materials.

**4. Lab Report.** In the standard version of CE300, a major objective of this laboratory exercise is to learn how to prepare a formal technical report, based on the format and guidelines provided in Section IV of the Department of Civil & Mechanical Engineering *Standards for Technical Reports*. However, in the standard version of CE300, cadets are assigned to do the lab exercise in teams of three or four cadets each. Given that you will be doing the lab on your own, the reporting requirements have been scaled down considerably. (See below.) Nonetheless, neatness, clarity, and quality of presentation are still important and will comprise a portion of your grade for the project.

The reporting requirement for this lab consists of the following two submissions:

**a. Initial Submission** (25 Points): Due on your scheduled date for Lesson 15. The intent of this submission is to ensure that you understand how to process and analyze the experimental data correctly before you complete the actual lab report. This submission will include:

- A cover page
- A complete Appendix A, B, C, and D for A36 Steel *only*.

You may submit this requirement as a Word file (preferred), or you may print it out, take digital photographs of each page, and submit the images. Use this latter option if you are unable to use the drawing tools in Excel to annotate your stress-strain graphs.

**b. Final Laboratory Report** (125 points). Due on your scheduled date for Lesson 21. In the standard version of CE300, a complete Lab #1 report would *normally* include the following:

- Title page
- Abstract
- Table of Contents

- List of Tables
- List of Figures
- List of Symbols
- 1. Introduction
- 2. Theory
- 3. Experimental Procedures
- 4. Results and Discussion
- 5. Conclusions
- Appendices A through H

Because you are doing the lab report as an individual product, rather than a team product, you are required to submit only the Results **and Discussion** section and Appendices A through F. Additional guidance on the preparation of these sections is as follows:

**(1) Results and Discussion.**

(a) Summarize your results using the example table below. Use one table for each material. Compare your results with accepted values of  $E$ ,  $\sigma_y$ ,  $\sigma_u$  and  $\epsilon_f$  for your materials. Use the web page [www.matweb.com](http://www.matweb.com) to look up the accepted values--and make sure to document this reference! Note that this website lists the fracture strain,  $\epsilon_f$ , as “Elongation at Break,” expressed in percent.

Table 1. Summary of Experimental Results for A36 Steel

	<b>Experimental Value</b>	<b>Accepted Value</b>	<b>% Difference</b>
<b>E (GPa)</b>			
<b><math>\sigma_y</math> (MPa)</b>			
<b><math>\sigma_u</math> (MPa)</b>			
<b><math>\epsilon_f</math> (mm/mm)</b>			

(b) Discuss the significance of your results. Compare the *ductility*, *resilience*, *brittleness*, *toughness*, *stiffness*, and *strength* of the three materials.

(c) Based on your (somewhat limited) knowledge of the UTT, discuss the sources of error in the experiment, and discuss the impact of this error on your data and/or results. What else, besides experimental error, might account for the differences between your experimental values and the accepted values?

(d) Discuss some possible practical uses for each of the three materials, based on their mechanical properties. **Focus on engineering applications** and discuss how the material properties support these practical uses. Make sure to document any external sources you use!

**(2) Appendix A – Raw Load-Deformation Data.** Provide the original data sheets in this appendix. It is considered good practice to always keep original experimental data, in case the validity of the results is ever questioned or to check if a number was incorrectly transferred.

**(3) Appendix B – Processed Stress-Strain Data.** Include your *processed stress-strain data tables* here. You must have one table for each material. These are not the same tables you included in your Results and Discussion section. Rather, this is the data from Appendix A, converted to *stress-strain* values for subsequent plotting in stress-strain curves. Use a spreadsheet to create these tables. **Ensure that your calculated values of ultimate stress, fracture stress, and fracture strain are included in these tables.**

**(4) Appendix C – Sample Calculations.** This appendix should include an example of all key calculations used to create the stress-strain tables in Appendix B. Select an actual raw data point for A36 steel, and show how the corresponding stress and strain were calculated. Be sure to include your calculation for cross-sectional area, and all appropriate unit conversions. Your results should exactly match the corresponding stress and strain values shown in Appendix B. In addition, show manual calculations for the Fracture Strain and Modulus of Elasticity for A36 steel.

These calculations can be done by hand and photographed, typed in the Equation Editor of MS Word, or worked in Mathcad.

**(5) Appendix D - Stress-Strain Curves for A36 Steel.** Include the two graphs described in Section 3.c above for A36 Steel.

**(6) Appendix E - Stress-Strain Curves for 6061-T6 Aluminum.** Include the two graphs described in Section 3.c above for 6061-T6 Aluminum.

**(7) Appendix F - Stress-Strain Curves for Gray Cast Iron.** Include the two graphs described in Section 3.c above for Gray Cast Iron.

**c. Format.** For both submissions, use the format for tables and graphs, as specified in the *C&ME Standards for Technical Reports*.

**d. Documentation.** Include a Works Cited page documenting all references you used in preparing the report.