AERO 214
Mechanical Properties
Tensile Testing Experiment

INTRODUCTION

Tensile testing is performed on materials to ascertain important mechanical properties like Young's modulus, tensile strength, yield strength, ductility and fracture strength. The fundamental purpose of a tensile test is to determine the deformation response of a given material under a specified load. This information is critical in the design of load carrying structural members. Tensile tests are performed with specimens of various geometries. Often, a specimen with a circular cross section is used. However, flat rectangular specimens are fairly common. In this laboratory experiment, we will be using a circular configuration.

OBJECTIVES

- To understand how a tensile test is performed and how to obtain the relevant material properties

- To determine the following properties for three given metallic specimens (Aluminum 2024, Aluminum 6061, and A36 Carbon Steel) using a uniaxial tensile test:

  Young's modulus, E
  Yield strength, σ_y
  Tensile strength, TS
  Toughness
  Ductility, %EL

- To ascertain the effect of strain hardening on the yield strength.

THEORY

A discussion on mechanical properties using tensile testing is provided in Chapter 7 of the Callister text. The geometry of the specimens used in this laboratory experiment is shown in Figure 1 below.

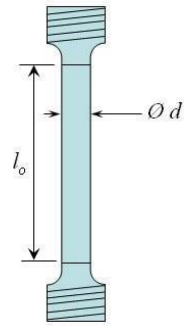


Figure 1. Schematic of a tensile specimen.

The section under test is the called the "gage length", with original length l_0, and diameter d. The applied stress can be calculated using equation 1 below:

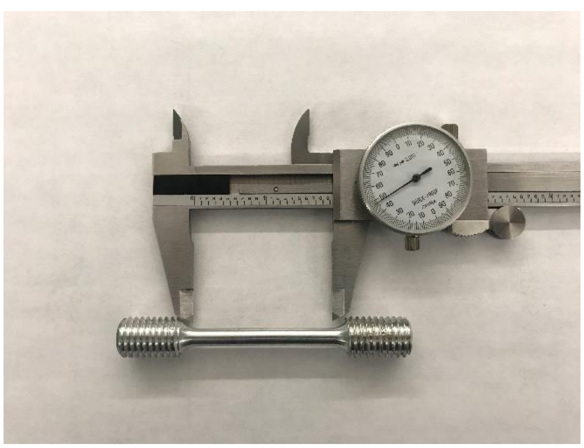
$$\sigma = \frac{F}{A} \qquad (1)$$

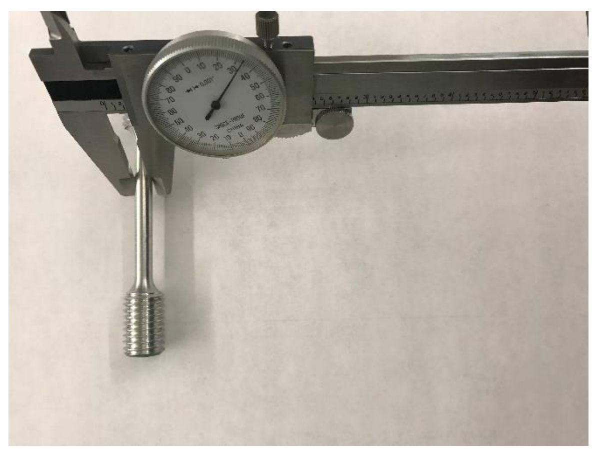
Where F is the force measured on the force display of the machine and A is the cross-sectional area of the specimen. The corresponding strain ε is given below:

$$\varepsilon = \frac{\Delta l_0}{l_0} \qquad (2)$$

Where Δl_0 is the **change** in the gage length. The Young's modulus is given by Hooke's law (ratio of stress to strain in the linear elastic region of the loading curve):

$$E = \frac{\sigma}{\varepsilon} \qquad (3)$$



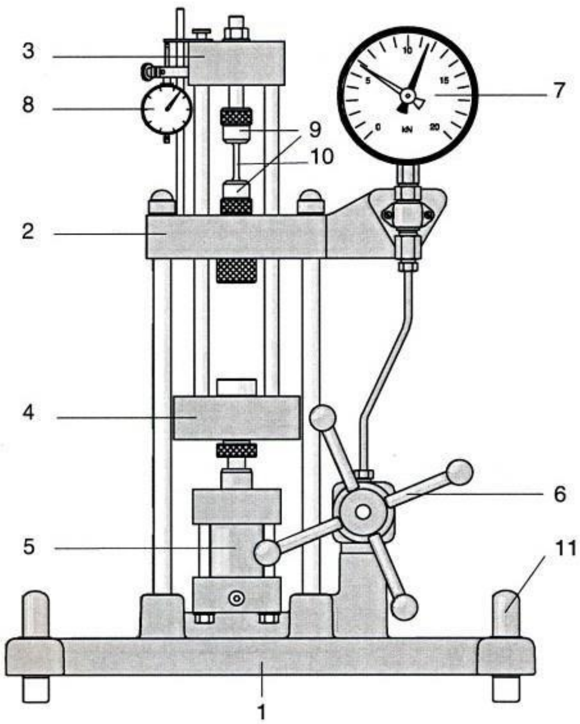


MATERIALS

Today, you will be testing three test specimens of different materials:

1. **Aluminum 6061**
2. **Aluminum 2024**
3. **ASTM-A36 Carbon Steel**

The schematic of the tensile testing equipment is shown in the figure below (observe carefully and understand the functions of the different parts):



- Machine base (1) with hand grips (11)
- Support with cross-head (2)
- Load frame with upper (3) and lower cross-member (4)
- Hydraulic system consisting of a main cylinder (5) and a master cylinder with a hand wheel (6)
- Force display (7)
- Elongation display via a dial gauge (8)
- Gripping heads (9) with sample (10)

Figure 2. Schematic of the tensile testing equipment.

TEST PROCEDURE

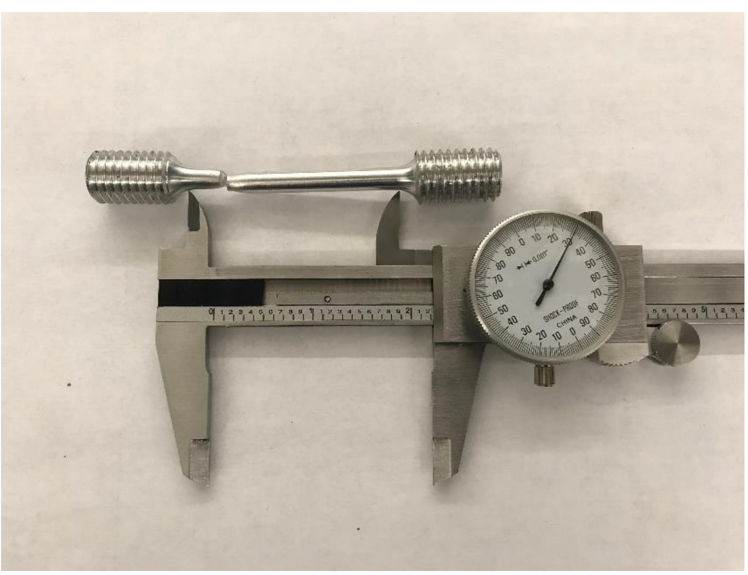
The general test procedure is as follows:

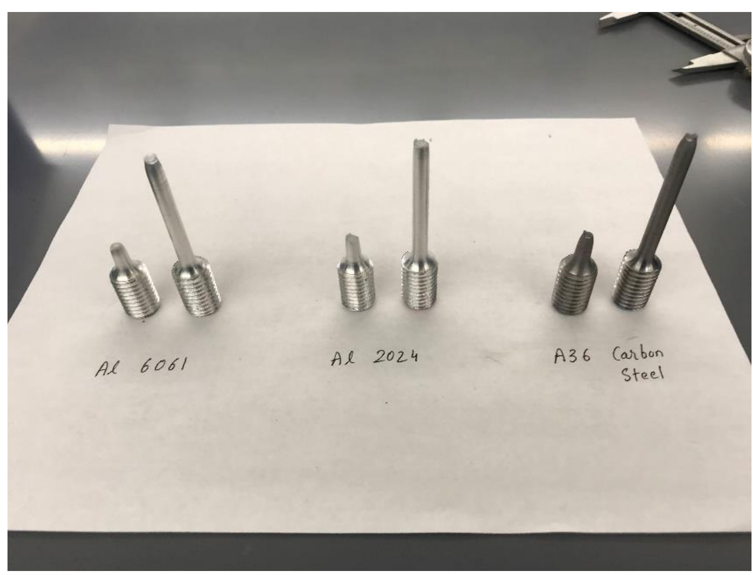
1) Identify the metal specimens assigned to your team. You will have two different metals anda total of three specimens.
2) Measure the dimensions necessary for analysis ($l_0$and d) on all your specimens. Refer to Figure 1.
3) Position your first specimen in the grips.
4) **Make sure the force display and the dial gage are on zero positions.**
5) Make sure that the “Max Force Pointer” – the red colored pointer in the force display– ison the zero position.
6) Apply loads **very slowly** by turning the handwheel in small increments and measure the corresponding deformation on the dial gage.
7) Calculate the stress corresponding to the load and the strain corresponding to the deformation and plot stress (y-axis) vs. strain (x-axis).

You will conduct a total of **four experiments** (1 test each with each aluminum specimen and 2 tests with the steel specimen). The specific test procedures for the experiments are given below:

Experiment #1 (Aluminum 6061) and #**2** (Aluminum 2024): Loading until fracture.

1. Make sure all pointers are on zero.
2. **Proceed in increments of 0.02 mm (2 divisions on the dial gage) for the first 30 readings. THEN, proceed in increments of 1 mm (1 revolution on the dial gage) till the specimens fracture.**
3. Write down the **load** and the **corresponding deformation** for **each increment**.
4. Stop when the specimen fractures. The specimen will fracture loudly in two parts.
5. Observe the fracture surface and comment on it in the report.
6. Put the fractured pieces together and measure the final gage length; you will require this for calculating ductility.





Experiment #3: Strain hardening of steel specimen.

1. Make sure all pointers are on zero.
2. **Proceed in increments of 0.02 mm (2 divisions on the dial gage) for the first 30 readings. THEN, proceed in increments of 1 mm (1 revolution on the dial gage) TILL you reach 13 kN on the force indicator.**
3. STOP at **13 kN** load.
4. Now, slowly release the load by 0.02 mm increments by turning the handwheel counter-clockwise.
5. Again, write down the load and the corresponding deformation as the load is released.
6. **Make a note of what the deformation is when the load falls back to zero.**
7. **Without removing the specimen from the grips, proceed to Experiment #4 below.**

Experiment #4: Continuation of Experiment #4 - Loading until fracture.

1. Make sure all pointers are on zero.
2. **Proceed in increments of 0.02 mm (2 divisions on the dial gage) for the first 30 readings. THEN, proceed in increments of 1 mm (1 revolution on the dial gage) till the specimen fractures.**
3. Write down the load and the corresponding deformation for **each increment**.
4. Stop when the steel specimen fractures. The specimen will fracture loudly in two parts.
5. Put the fractured pieces together and measure the final gage length; you will require this for calculating ductility.

REPORTING REQUIREMENTS

1. Plot stress vs. strain for each material and each of the experiments. (10 points)
2. For each material, determine the modulus of elasticity using Equation 3. **Use linear regression to calculate modulus, use only the linear elastic portion of the stress-strain diagrams obtained from your experiments. (Report modulus in GPa)** (20 points)
3. In the linear regression, what is the R^2 value and the equation for the fitted line? What does the R^2 value tell us? (5 points)
4. Compare the calculated values of modulus of elasticity values with those reported in the literature (Appendix in textbook or online source) (5 points)
5. Calculate and report yield strength, tensile strength, fracture stress, ductility and toughness for all specimens. Specify clearly what methods you are using to estimate these values. Compare them to published data whenever possible. **(Report strength in MPa).** Show calculation in the appendix, include equations and sample calculation. (10 points)
6. Compare the yield strength of steel as obtained from Experiment #3 and #4. Comment on the difference. (5 points)
7. Calculate uncertainty and determine the number of significant figures for all reported values in the results table, report uncertainty as xx±xx. Show calculation in the appendix, include equations and sample calculation. (20 points).
8. Prepare results as a technical report (Format: see Handout; Maximum Length 5 pages plus tables and graphs). Be sure to address all reporting requirements. **Be sure to address all reporting requirements. Final results with the uncertainty MUST be shown using the "Results Table" included in the next page.**

9. Include all raw data in an appendix. Include all calculations in an appendix as well.

<u>Note:</u> Those who miss the lab or do not contribute to the lab report will not get credit.

Results Table

	Aluminum 6061	Aluminum 2024	ASTM- A36 Steel
Young's Modulus			
Yield Strength			Compare for Experiment #3 and #4
Tensile Strength			
Fracture Stress			
Ductility			
Toughness			

** Report results with uncertainty for all reported values in the table as xx±xx

AERO 214-500
Technical Laboratory Report Format

The following sections must be included in each Technical Laboratory Report.

1. TITLE PAGE

This is the cover page and should present the report in a professional manner. The following should be included:

a. Title of Report
b. Authors (Team #, Team Leader(s) for this report, other Team Members)
c. Date

2. TABLE OF CONTENTS

This page should include all sections of the report, figures, tables, and appendices and their corresponding page numbers.

3. ABSTRACT

This is a brief summary (6-10 sentences) of what was done, what was found, and why it is important.

4. INTRODUCTION

This section provides motivation and a general summary of the experiment. Any definitions, theory, and background literature are included in this section.

5. EXPERIMENTAL PROCEDURE

This section describes step-by-step the procedures used to conduct the experiment(s). If an ASTM standard test method was used, only the standard test number needs to be cited along with any deviations from this standard method.

6. RESULTS

This section includes summary data in tables and figures used in the analysis (next section) and text to describe these tables and figures. Each table and figure must have a number and be cited in the text. This section does not include raw data.

7. DISCUSSION

In this section, results presented in the previous section are analyzed and discussed in response to the reporting requirements. Additional figures may also be added. Any problems encountered in the experiment should also be highlighted as well as the effects of these problems on the results and analysis and methods by which to avoid these problems in the future.

8. CONCLUSIONS AND RECOMMENDATIONS

This section contains summary conclusions based on the analysis, positive aspects of the experiment in terms of learning, and recommendations for improving and/or expanding the experiment.

9. APPENDICES

This section (if necessary) contains specific calculations and raw data.