CE 265 Lab No. 2:

Tensile Testing of Steel

See web for typical report format including:

TITLE PAGE, ABSTRACT, TABLE OF CONTENTS,

LIST OF TABLE, LIST OF FIGURES

1.0 - INTRODUCTION

See General Lab Report Format in Appendix A

2.0 - DATA ANALYSIS

The purpose is to calculate mechanical properties of steel, namely Modulus of Elasticity, yield stress, ultimate stress, resilience, fracture toughness, failure strain, and % area reduction.

2.1 - Details of Samples

- Briefly describe the samples used for this experiment as summarized in Table 2.1. Mention physical state, surface imperfections and so on.

Table 2.1 -Specimen Condition and Loading Details

<table>
<tr><th colspan="2">Specimen</th><th>Symbol</th><th>Loading Details</th></tr>
<tr><td rowspan="3">Steel (1020)</td><td>As Received (AR)</td><td>S/AR</td><td>Continuous loading to failure</td></tr>
<tr><td>As Received and Cold Worked (S/AR-CW)</td><td>S/AR-CW</td><td>Load beyond yield, unload and reload to failure</td></tr>
<tr><td>As Received, Cold Worked and Aged (/AR-CW-A)</td><td>S/AR-CW-A</td><td>Load beyond yield, unload, age, reload to failure</td></tr>
<tr><td>Stainless</td><td>Type 304</td><td>SS</td><td>Continuous loading to failure</td></tr>
<tr><td>Brass</td><td></td><td>B</td><td>Continuous loading to failure</td></tr>
<tr><td>Copper</td><td></td><td>C</td><td>Continuous loading to failure</td></tr>
</table>

S – Steel, AR – As Received, CW – Cold Worked, A – Aged

2.2 - Specimen Geometry

Describe the geometry of the specimens using Figure 1 and Table 2.2.

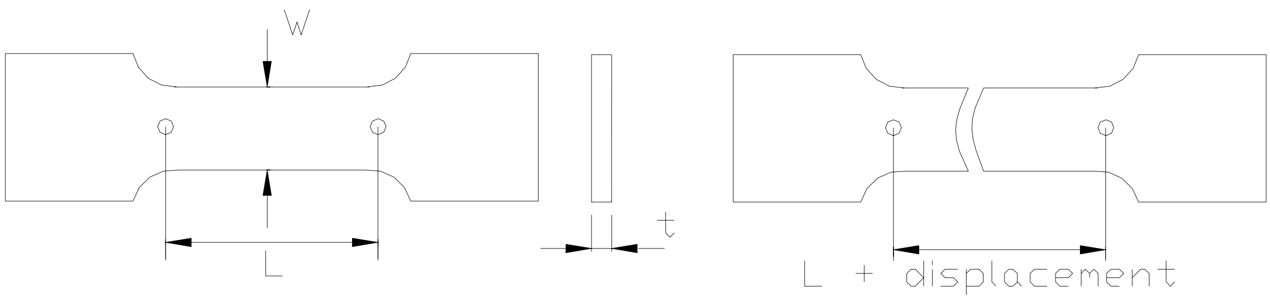


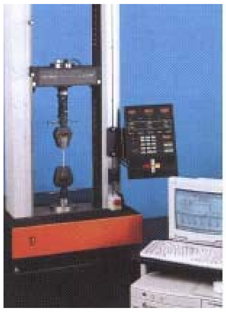
Figure 1 – Typical Specimen

Table 2.2 - Specimen Geometry (mm)

Specimen	Width (W_o)	Thickness (t_o)	Gauge Length (L_o)	Cross Sectional Area (A_o)
S/AR				
S/AR-CW				
S/AR-CW-A				
SS				
B				
C				

2.3 - Details of Testing Equipment

- Describe the Instron Testing Machine (briefly)
- Report the Units of machine measurements: displacement in mm and load in kg. You will have to multiply the load in kg by acceleration due to gravity (9.81 m/s^2) to find the load in Newtons.
- The following picture is off the Internet; a picture of the actual machine in the lab is better.



2.4 - Measured Data

- Describe the data you will determine from the load/displacement graphs produced by the testing machine.
- Refer to Tables 2.3 and 2.4 for this task.

Table 2.3 - Specimen Dimensions After Tensile Testing (mm)

Specimens	Width (W_f)	Thickness (t_f)	Gauge Length (L_f)	Cross Sectional Area (A_f)
S/AR				
S/AR-CW				
S/AR-CW-A				
SS				
B				
C				

Table 2.4 – Measured Values from load – displacement graphs.

Date:				
Testing Information: Measured Values				
Group No. and Names:				
Notes:				
Specimen	**Yield Load (kg)**	**Yield Displacement (mm)**	**Maximum Load (kg)**	**Failure Displacement (mm)**
S/AR				
S/AR-CW				
S/AR-CW-A				
SS				
B				
C				

2.5- Plots of Engineering Stress vs. Strain and True Stress vs. True Strain

- You will want to explain what these graphs are and how they are helpful in engineering. You may choose to include these graphs in the report itself or include in an Appendix.
- Plots required for all specimens.
- The graph displays loads in kg, therefore multiply by acceleration due to gravity (9.81 m/s^2) to get the force in Newtons.

- Engineering Stress

$$\sigma_E = \frac{P}{A} \qquad \text{(Equation 1)}$$

where P is the load in Newtons (force read from the load-disp. Graph, $P = w \times g$, where w is the load in kg, and g=9.81 m/s^2) and A_o (Table 2.2) is the original cross sectional area.

$$\sigma_E(Pa) = \frac{P(Newtons)}{A_o(m^2)}$$

$$\sigma_E(MPa) = \frac{P(Newtons)}{A_o(mm^2)}$$, 1 MPa = 10^6 Pa

- Engineering Strain is the change in length of the specimen divided by its original length.

$$\varepsilon_E = \frac{\Delta L}{L_o} \qquad \text{(Equation 2)}$$

where L_o is the original length (Table 2.2) and ΔL is the change in length,

$$\Delta L = L_f - L_o \qquad \text{(Equation 3)}$$

where L_o is the original length (Table 2.2)

- True Strain is the logarithm (ln) of instantaneous length divided by the original length.

$$\varepsilon_T = \ln\left(\frac{L_i}{L_o}\right) \qquad \text{(Equation 4)}$$

where L_i is the instantaneous length and L_o is the original length. It can be obtained from ε_E as:

$$\varepsilon_T = \ln(1+\varepsilon_E) \qquad \text{(Equation 5)}$$

where ε_E is Engineering Strain. This formula is valid up to the point of neck initiation.

- True Stress (σ_T) is the Load divided by the instantaneous cross-sectional area.

$$\sigma_T = \frac{P}{A_i} \qquad \text{(Equation 6)}$$

where P is the load in Newtons, and Ai is the instantaneous cross-sectional area. It can be obtained from

$$\sigma_T = \sigma_E (1+\varepsilon_E) \qquad \text{(Equation 7)}$$

where ε_E is engineering strain and σ_E. is the engineering stress.

2.6- Mechanical Properties

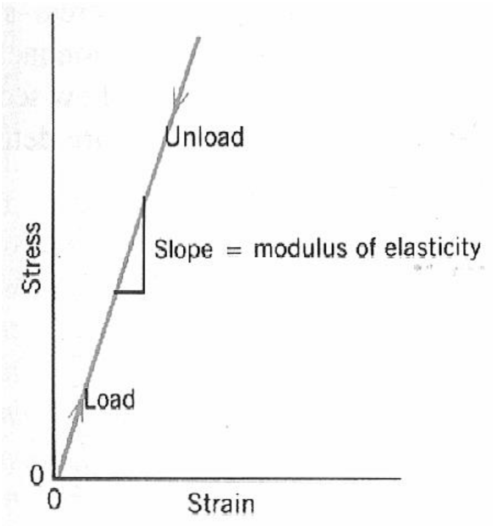
- Explain what the mechanical properties are (Modulus of Elasticity, yield stress, ultimate stress, resilience, fracture toughness, failure strain, and % area reduction) and why they are important.
- Follow the formulae below.

Table 2.5 Mechanical Properties.

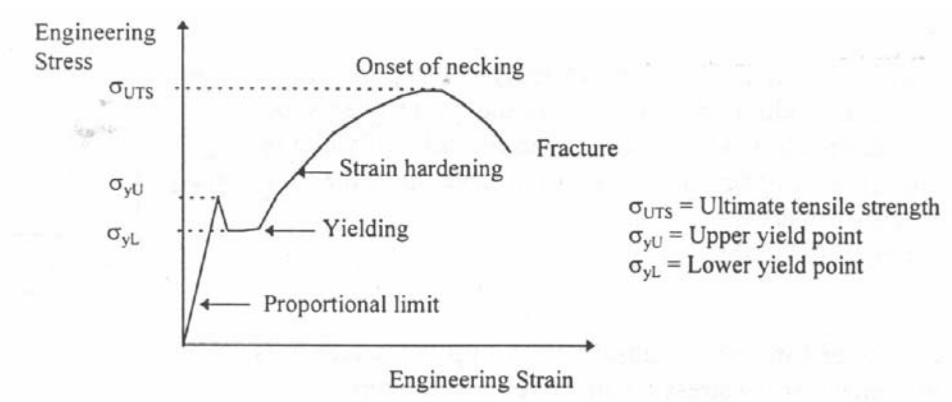
Date:								
Testing Information: Measured Values								
Group No. and Names:								
Notes:								
Specimen	Modulus of E. (GPa)	Yield Stress (MPa)	Ultimate Stress (MPa)	Ductility	Resilience (Mpa)	Fracture Toughness (Mpa)	Failure Strain	% Area Reduction
S/AR								
S/AR-CW								
S/AR-CW-A								
SS								
B								
C								

- <u>The modulus of Elasticity (E)</u> is the slope of the linear part of the stress strain graph. The slope is rise over run, or vertical projection divided by horizontal projection; as shown below.

$$E = \Delta\sigma / \Delta\varepsilon . \qquad \text{(Equation 8)}$$



- The yield stress (σ_y) of a material is the stress at the point where linear behaviour of stress vs. strain stops. This is the upper yield point on this picture.



- The Ultimate Stress is the stress at the point where necking begins.
- Ductility is a measure of how much a material will stretch or deform.

  $\text{Ductility} = [(L_f - Lo)/Lo] \times 100$ (Equation 9)

where L_f (Table 2.3) is the final length of the specimen and Lo (Table 2.2) is the initial length.

- Resilience (U_r) is the amount of energy that can be absorbed during the linear behaviour of the specimen. This is the area under the linear portion of the stress-strain plot up to the yield point.

$U_r = \frac{1}{2} \times \sigma_y \times \varepsilon_y$ (Equation 10)

where the strain (ε_y) and stress (σ_y) are measured at the yield point.

- Toughness is the amount of energy the specimen can absorb until failure. This is the area under the stress-strain graph up to the failure point. This is easily done by counting the squares under the line on graph paper. Make sure you correctly calculate the dimensions and units of you squares. If you have electronic data, it toughness is easy to calculate by numerical integration.
- Failure strain is the strain at the point of failure.
- % Area reduction is another measure of ductility.

  % Area Reduction $= \frac{(Ao - A_f)}{Ao} \times 100$ (Equation 11)

  where A_o (Table 2.2) is the initial cross sectional area and A_f (Table 2..3) is the final cross sectional area.

3.0 - DATA INTERPRETATION

Use this section to discuss the effects of cold working and aging on the mechanical properties.

3.1 - Cold Working (Strain Hardening)

In this section, explain the cold working and its effects on strength and ductility. Cold working is the process used to increase the yield stress of a specimen. A specimen is cold worked when it is stretched beyond its elastic limit. The yield stress the material was taken to will become its new yield stress. The specimen will however undergo permanent deformation. In brief, cold working makes a specimen less ductile as it increases its yield stress.

3.2 - Aging (Precipitation Hardening)

Aging is another process used to decrease ductility as it raises the yield stress of a material. Aging is also called precipitation hardening. Aging consists of placing a specimen in a furnace for approximately 90 minutes or until the small particles of one of the composition metals starts to precipitate on the other or others. This makes the material stronger and lowers its ductility.

3.3 - Mechanical Properties

This is where you will discuss and explain the mechanical properties of the specimens and how they changed according to the treatment they underwent or the type of metal alloy. You should also explain the importance of these mechanical properties to engineering design.

4.0 - CONCLUDING REMARKS

See General Lab Report Format on web

5.0 - REFERENCES

See General Lab Report Format on web.

APPENDICES

If you have included other things in the appendices, make sure you created an appendix label for each. Appendices are to be numbered in order that they appear. You may choose numbers or letters. Also include in the appendices, the graph created by the Instron, extra pictures, and any other material or calculation methods you used to obtain your material properties.

- Sample Calculations
- Plots and Raw Data

OTHER INFORMATION

You may also choose to add extra sections if needed to provide additional information such as error analysis of test data.