MSE 527L - Testing of Materials in Tension

Object: The object of this experiment is to measure the tensile properties of steel, copper and aluminum at a constant strain rate on the tension testing machine using crosshead and laser extensometer.

Background: For structural applications of materials such as bridges, pressure vessels, ships, and automobiles, the tensile properties of the metal material set the criteria for a safe design. Polymeric materials are being used more and more in structural applications, particularly in automobiles and pressure vessels. New applications emerge as designers become aware of the differences in the properties of metals and polymers and take full advantage of them. The analyses of structures using metals or plastics require that the data be available.

Stress-Strain: The tensile properties of a material are obtained by pulling a specimen of known geometry apart at a fixed rate of straining until it breaks or stretches to the machines limit. It is useful to define the load per unit area (stress) as a parameter rather than load to avoid the confusion that would arise from the fact that the load and the change in length are dependent on the cross-sectional area and original length of the specimen. The stress, however, changes during the test for two reasons: the load increases and the cross-sectional area decreases as the specimen gets longer.

Therefore, the stress can be calculated by two formulae which are distinguished as engineering stress and true stress, respectively.

(1) **$\sigma = P/A_o$ = Engineering Stress** (lbs/in^2 or psi)
P = load (lbs)
A_o = original cross-sectional area (in^2)

(2) **$\sigma_T = P/A_i$ = True Stress**
A_i = instantaneous cross-sectional area (in^2)

Likewise, the elongation is normalized per unit length of specimen and is called strain. The strain may be based on the original length or the instantaneous length such that

(3) $\varepsilon = (l_f - l_o)/ l_o = \Delta l / l_o$ = Engineering Strain, where

l_f = final gage length (in)
l_o = original gage length (in)

(4) $\varepsilon_T = \ln (l_i / l_o) = \ln (1 + \varepsilon)$ = True Strain, where

l_i = instantaneous gage length (in)
ln = natural logarithm

For a small elongation the engineering strain is very close to the true strain when $l = 1.2\ l_o$, then $\varepsilon = 0.2$ and $\varepsilon_T = \ln 1.2 = 0.182$. The engineering stress is related to the true stress by

(5) $\sigma_T = \sigma(1 + \varepsilon)$

The true stress would be 20% higher in the case above where the specimen is 20% longer than the original length. As the relative elongation increases, the true strain will become significantly less than the engineering strain while the true stress becomes much greater than the engineering stress. When l= 4.0 l_o then ε = 3.0 but the true strain =ln 4.0 = 1.39. Therefore, the true strain is less than 1/2 of the engineering strain. The true stress (σ_T) = σ(1+ 3.0) = 4σ, or the true stress is 4 times the engineering stress.

Tensile Test Nomenclature: The tensile test data are characterized by terminology shown in Figure 4-1.

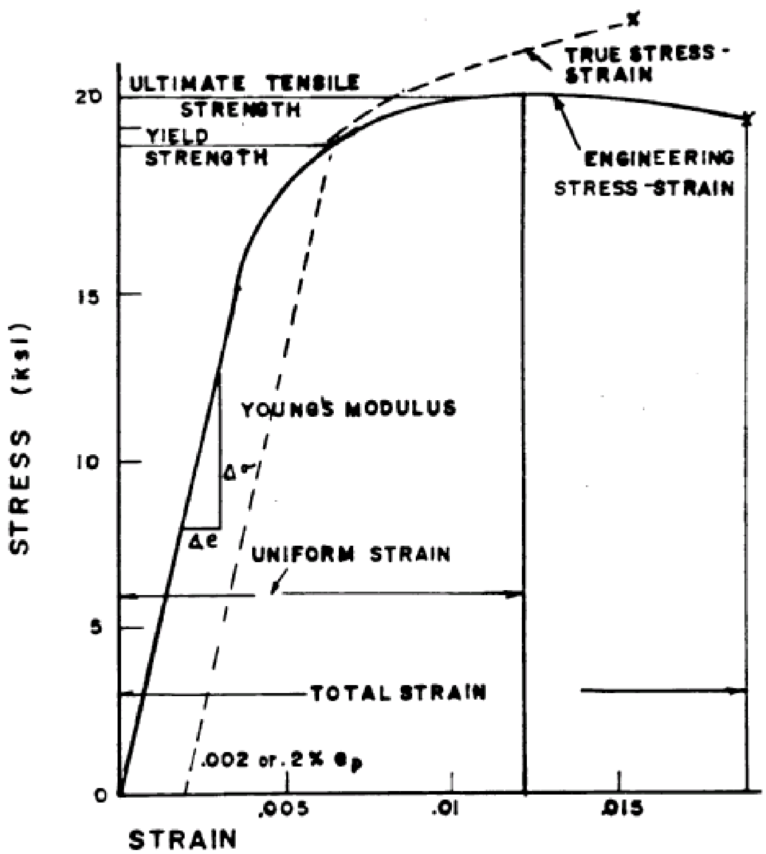

Figure 4-1: Engineering Stress-Strain Curve

The material test curves have a region where the deformation caused by the stress is elastic, or not permanent. This means when the stress is removed the specimen returns to its original length. At stresses greater than a certain value, a portion of the strain becomes permanent or plastic. The stress required to cause a 0.2% plastic strain, or off-set, is called the yield stress.

Ductility is measured as % elongation, representing the ability to deform in the plastic range

(6)
$$\%elongation = \left(\frac{l_f - l_0}{l_0} \right) 100$$

Equipment
United Tensile Testing Machine: floor-mounted (**20,000 lb. capacity**)
Dial Calipers
Ruler

Procedure
The United machine is controlled and records data using a DOS computer controller. You will be provided with 3 metal specimens. Use a strain **rate of 0.2 inches per minute for the metals**.

Using dial calipers measure (in the reduced area)**:**
1) the **thickness** of the specimen to +.002 inches.
2) the **width** of the specimen to $\pm$ 0.02 inch.

Place 2 small pieces of **metallic tape** roughly **2 inches apart** (depending on the reduced area of the sample) on each tensile sample, then put them in the grips as instructed and tighten the clamps securely. The distance between the metallic tapes will be entered into the computer display for the **gage length**. Test will be conducted using the **laser extensometer**.

The settings for this experiment are:

Sample	Range setting for computer
Copper	(20,000 lbs. full scale)
Steel	(20,000 lbs. full scale)
Aluminum	(20,000 lbs. full scale)

Data Needed:
Original specimen: width, thickness, gage length
After fracture: load and percent elongation (total strain)
DOS files with test data

Write Up
Prepare a memo report on the results of the tests. The report should contain **3 Figures (graphs) that contain an overlay of engineering and true stress-strain curves** from the tensile tests for each material graphed using Excel. **Label engineering curves** to show **Young's Modulus, Yield Stress, Ultimate Tensile Strength, and Total Strain** (also **label values;** for example, Young's modulus = 41000 psi). D**iscus**s t**hese values in your report and compare** them with **published values for the same alloys**. **You will also calculate and plot the strain hardening coefficient for each sample.** Discuss your 4 graphs, the errors involved in this experiment and their sources.

Memo Report includes:
Compare graphs for **engineering** stress-engineering strain, and **true** stress-true strain using data from tensile tests for each material (3 graphs; 2 curves overlaid per graph).
Label Engineering Curves only
Young's Modulus labeled **neatly using Excel** (Include values on graph).
Yield Stress labeled **neatly using Excel** (Include values on graph).
Total Strain labeled **neatly using Excel** (Include values on graph).
Ultimate Tensile Strength labeled **neatly using Excel** (Include values on graph).
Experimental values for E, σ_{yld}, σ_{ult}, total elongation compared to published values. **Include table** with compared values and measured data.
Calculate and plot the **strain hardening coefficient** for each sample (3 graphs with equations for line fitting shown on graph).
Discussion of errors in this experiment and their sources.

References

McClinock, Mechanical Behavior of Materials
Dieter, Mechanical Metallurgy
Nielsen, Mechanical Properties of Polymers
Schmitz, Testing of Polymers
Van Vlack, Elements of Materials Science and Engineering, Chapter 1 and 6

Glossary of Terms

Understanding the following terms will help in understanding this experiment:

Ductility - The ability of a material to be permanently deformed without breaking when a force is applied.

Elastic deformation - Deformation of the material that is recovered when the applied load is removed. This temporary deformation is associated with the stretching of atomic bonds.

% Elongation - The total percent increase in the length of a specimen during a tensile test.

Engineering strain - Increase in sample length at a given load divided by the original (stress-free) length.

Engineering stress - The applied load, or force, divided by the original cross-sectional area of the material.

Engineering stress-strain curve - A plot of the Engineering stress versus the Engineering strain.

Hooke's law - the linear relationship between stress and strain in the elastic portion of the stress-strain curve.

Modulus of elasticity - Young's modulus, or the slope of the stress-strain curve in the elastic region.

Necking - Local deformation of a tensile specimen. Necking begins at the tensile point.

Offset yield strength - yield strength obtained graphically that describes the stress that gives no more than a specified amount of plastic deformation.

Plastic deformation - Permanent deformation of the material when a load is applied, then removed.

% Reduction in area - The total percent decrease in the cross-sectional area of a specimen during the tensile test.

Tensile strength - The maximum engineering stress experienced by a material during a tensile test (ultimate tensile strength).

Tensile test - Measures the response of a material to a slowly applied uniaxial force. The yield strength, tensile strength, modulus of elasticity, and ductility are obtained.

True strain - The actual strain produced when a load is applied to a material.

True stress - The load divided by the actual area at that load in a tensile test.

Yield strength - The stress applied to a material that just causes permanent plastic deformation.