

Experiment 4 - Testing of Materials in Tension

Object: The object of this experiment is to measure the tensile properties of two polymeric materials, steel and aluminum at a constant strain rate on the Tension testing machine.

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) $\sigma = P/A_o = \text{Engineering Stress (lbs/in}^2 \text{ or psi)}$
P = load (lbs)
A_o = original cross-sectional area (in²)
- (2) $\sigma_T = P/A_i = \text{True Stress}$
A_i = instantaneous cross-sectional area (in²)

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) $\epsilon = (l_f - l_o) / l_o = \Delta l / l_o = \text{Engineering Strain, where}$

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

- (4) $\epsilon_T = \ln (l_i / l_o) = \ln (1 + \epsilon) = \text{True Strain, where}$

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 $\epsilon = 0.2$ and $\epsilon_T = \ln 1.2 = 0.182$. The engineering stress is related to the true stress by

- (5) $\sigma_T = \sigma(1 + \epsilon)$

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 $l = 4.0 l_0$ then $\epsilon = 3.0$ 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 $(\sigma_T) = \sigma(1 + 3.0) = 4\sigma$, 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.

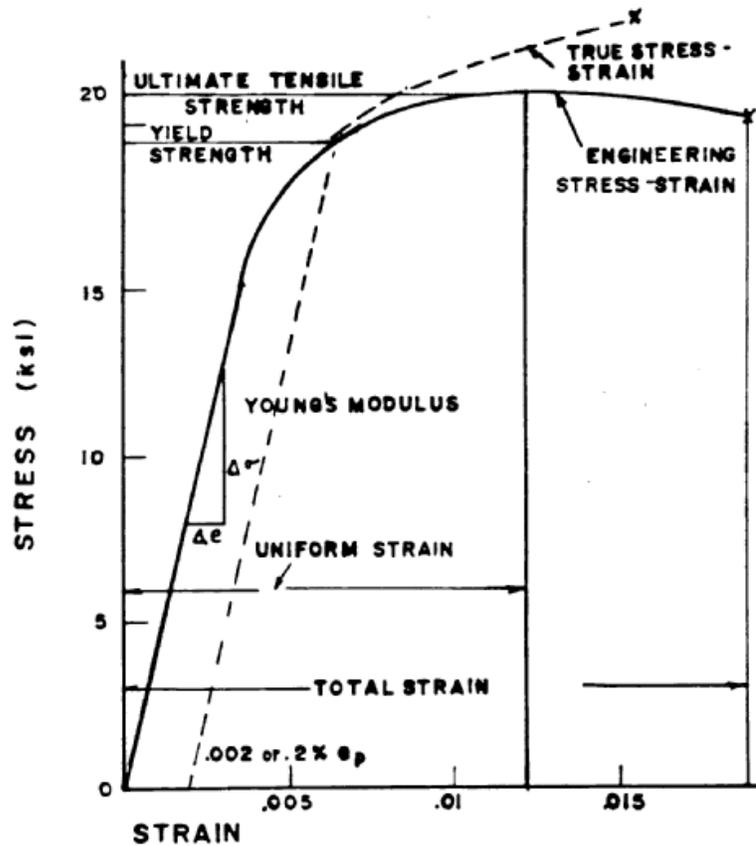


Figure 4-1: Engineering Stress-Strain Curve

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

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

Equipment

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

Procedure

You will receive 4 specimens (high density polyethylene, low density polyethylene, steel and aluminum).

Using calipers measure (in the reduced area):

- 1) the **thickness** of the specimen to ± 0.002 inches.
- 2) the **width** of the specimen to ± 0.02 inch.

Make sure to record the specific metal alloy, original specimen width, thickness, gage length, and after fracture load and percent elongation (total strain).

Place the specimen as instructed and tighten the clamps securely. The original crosshead distance (**gage length**) will be measured with a ruler after the sample has been placed firmly in the grips. The gage length is the distance from the top of the lower clamp to the bottom of the upper one. Measure the gage length to ± 0.1 inch.

MSE 227 LAB – Tensile Machine Operation

Click on **DATUM** shortcut on the Desktop (wait for program to finish loading)

Click on Template for:

- MSE 227 Aluminum or Steel sample - testing rate will be 0.2 inch/minute
- MSE 227 Polymer sample - testing rate will be 2.0 inch/minute

Click on **SAMPLE INFORMATION** tab:

Enter

- Gage length
- Width
- Thickness

(Make sure to ENTER the information, so that it calculates the Area correctly)

The **CONTROL SEGMENT** tab shows the testing rate for the given set up.

Tighten the grips on the sample; you can see the force you are applying on the computer screen. You want to be sure the grips are secure (hopefully with no more than 5lb force preload).

Click on **TEST** when ready to begin testing.

Make sure to record test number, so you can find your data.

Click on **REPORT** to Export your file.

To retrieve data go to:

Computer → Local disk (C) → Datum 5 → DFW → ExpPlots

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.

Write Up

Prepare a memo report on the results of the tests. The report should contain **4 Figures (graphs) that contain an overlay of engineering and true stress-strain curves** from the tensile tests for each material. All graphs should be 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). **Discuss these values in your report and compare them with published values for the same alloys**. Discuss your 4 graphs, the errors involved in this experiment and their sources.

References

- McClinock, Mechanical Behavior of Materials
- Dieter, Mechanical Metallurgy
- Nielsen, Mechanical Properties of Polymers

	Poor	Fair	Average	Good	Excellent
Memorandum Format Used	1	2	3	4	5
Spelling, grammar & punctuation correct	1	2	3	4	5

Report includes:	Poor	Fair	Average	Good	Excellent
Compare graphs for engineering stress-engineering strain, and true stress-true strain using data from tensile tests for each material (4 graphs total; 2 curves overlaid per graph).	4	8	12	16	20
Label Engineering Curves only					
<u>Young's Modulus</u> labeled neatly using Excel (Include values on graph). <u>Show calculations.</u>	1	2	3	4	5
<u>Yield Stress</u> labeled neatly using Excel (Include values on graph).	1	2	3	4	5
<u>Total Strain</u> labeled neatly using Excel (Include values on graph).	1	2	3	4	5
<u>Ultimate Tensile Strength</u> labeled neatly using Excel (Include values on graph).	1	2	3	4	5
Experimental values for E, σ_{yld} , σ_{ult} , total elongation compared to published values . Include table with compared values and measured data.	2	4	6	8	10
Discussion of errors in this experiment and their sources.	1	2	3	4	5

	Poor	Fair	Average	Good	Excellent
Overall level of effort apparent	1	2	3	4	5
Quality of graphs	1	2	3	4	5
Quality of Abstract	1	2	3	4	5
Quality of work description	1	2	3	4	5
Quality of conclusions	1	2	3	4	5