Laboratory 1  
Topic: Uniaxial Tension Test

Objectives

1. To determine the common stress-strain parameters which can be obtained from a uniaxial tension test. These include: Young's modulus, proportional limit, yield stress and ultimate stress (also can be called yield strength and ultimate strength).

2. To familiarize the students with the common procedures and instrumentation used to conduct uniaxial tension tests.

Introduction

In this laboratory, you will conduct tension tests on two metal alloys. They are A36 hot rolled structural steel and 1018 cold rolled steel. Your TA will give you one specimen, either hot or cold rolled, to test. Following the experiments, all of the students in the group should arrange to exchange the appropriate data, so that you will have data for five to six specimens of each type (via Box at: box.nd.edu[http://box.nd.edu]). (Note: Each person will share their calculated values of Young’s Modulus, ultimate stress, yield stress, etc. with the rest of the group, but should not share their raw data.) Report on the results of the measurements, and calculate mean and standard deviations of the properties.

The uniaxial tension test is one of the most widely used tests to measure the mechanical properties of materials. The concepts of stress and strain are essential to understanding the results of the test. Carefully review the information in chapter two of the text before performing the laboratory, and ask your TA or the instructor to explain any concepts you don’t understand.

The purpose of the tension test is to measure the stress-strain response of a material. This is accomplished by subjecting a rod of material to increasing axial elongation until it breaks. The result of such test is usually reported in the form of a stress-strain diagram (Fig. 1). The stress-strain diagram is usually plotted with the stress in the vertical axis and the strain in the horizontal axis. Point O, at the origin, corresponds to the unloaded specimen.

 Initially, between points O and A, the relation between the stress and strain is linear. The slope of this line is called Young's modulus or modulus of elasticity and is denoted by the letter $E$. So in this linear elastic region we have $\sigma = E \epsilon$. Loading and unloading occur along the same line, that is, if the bar is unloaded from a stress between 0 and A, the bar recovers its initial dimensions. Point A is called the proportional limit since, if the stress increases past $\sigma_{pl}$, the relation between stress and strain ceases to be linear. Generally, for stresses higher than $\sigma_{pl}$, the specimen does not...
recover its initial dimensions when it is unloaded, the material is said to have deformed plastically. For example, if the stress is brought back to zero from point B, unloading occurs along the line BC (which has a slope nearly equal to $E$), so a permanent strain OC remains after the stress is relieved.

It can be very difficult to determine the precise value of stress at which the material becomes plastic, so it is conventional to define a yield stress using the 0.2% strain offset criterion. In order to find the yield stress, draw a line parallel to OA but with a strain offset of 0.2% as shown by the dashed line in Fig. 1. The intersection of this line with the stress-strain curve defines the yield stress or stress at the yield point $\sigma_y$.

The range between A and D is called the work-hardening range since the stress increases with increasing straining (Figure 1). Point D represents the maximum or ultimate stress ($\sigma_{ult}$). Straining past point D results in “necking” of the specimen as shown in the insert and finally the specimen fractures at the neck at point F. (Figure 1)

Some metals, such as mild steel, have stress-strain curves that resemble that shown in Fig. 2. The elastic region OA is similar to the one in the case already discussed. Yielding, however, occurs quite abruptly at point A and the stress usually drops suddenly to point B. The stress at A is called the upper yield stress ($\sigma_{yu}$) while the stress at B is called the lower yield stress ($\sigma_{yl}$). The stress remains approximately constant between points B and C. Straining beyond point C causes the material to strain harden. After point C, the stress-strain response has very similar characteristics to those of the case shown in Fig. 1.

Other materials such as wood or rubber can have stress-strain curves that can be significantly different from the ones presented here. The stress-strain response of a material can also depend on environmental factors such as temperature, humidity, chemical treatment, or the rate of loading.

Figure 1: Stress-strain curve typical of some metals

Figure 2: Stress-strain curve typical of mild steel
Instrumentation

The main instruments used in this experiment are the uniaxial testing machines. These machines were manufactured by the Applied Test Systems Corporation and we usually refer to them as the “ATS machines," or Load Frames. The specimen is held between two wedge grips, each attached to a crosshead. The upper crosshead is fixed to the vertical columns and remains stationary. The lower crosshead is connected to a screw and an electric motor, which causes it to move up or down, at a prescribed speed selected by the user.

The ATS machines have been fitted with the necessary instrumentation to measure the force applied to the specimen as well as the movement of the lower crosshead (Fig. 3). The force applied to the specimen is measured by a load cell which is located between the upper grip and crosshead. The load cell output is an electrical signal whose voltage is proportional to the measured load. The constant of proportionality (or calibration factor) is 1,000 pounds per Volt. The displacement of the lower crosshead is measured by a special displacement transducer (called Direct Current Linear Variable Differential Transformer, or LVDT for short) whose output is also an electrical signal whose voltage is proportional to the distance traveled by the lower crosshead. The calibration factor of the LVDT is approximately 0.2 inches per Volt. Your TA will review with you the experimental set-up and the operation of the equipment.

In order to make accurate measurements of the strain in the specimen, you will use a special transducer called the axial extensometer mounted on the test section of the specimen. Its output is an electrical signal that is proportional to the measured strain. The extensometer that you will be using has been calibrated and has a calibration constant of approximately 0.027 per Volt (recall strain is a dimensionless quantity).

The output of each transducer will be monitored using a computer-based data acquisition system. The system consists of a PC, which has a special data acquisition board (Fig. 4). The power supplies provide the appropriate electrical power needed to operate the transducers. The output from each of the transducers is fed into the multiplexer. The multiplexer is an electronic switch that connects the rest of the data acquisition system to one transducer at a time. The signal selected by the multiplexer is then fed to the analog-to-digital converter, which reads an analog voltage (just like a voltmeter) and converts the information into digital form appropriate for storage and processing by the computer.
The software required to run the uniaxial tests will be loaded and ready to go when you get to the lab. Your TA will show you how to operate the data acquisition system.

**Data Reduction**

The data collected by the system will be arranged in three columns in the following order: Load cell output, displacement transducer output, and extensometer output. The displacement and strain values may start at a value other than zero. You should correct the data by subtracting off the initial displacement, which you can detect by noting when the force value starts to increase. Data will be recorded in units of volts. Your TA will give you the calibration constants to convert units of volts into physical units. The calibration constants are different for each Load Frame. Be sure to record your specimen type and machine number.

**Procedure**

The procedure is detailed in steps. If you have questions, ask your TA.

1. Obtain the specimen to be tested from your TA. The specimens are color coded: specimens with a white end are cold-rolled, black are hot-rolled.
2. Using the calipers and ruler provided, measure the diameter of the specimens and the length of the test section. Record your measurements.
3. One of the members of the group must log in to the computer to store the data
4. Double click on the icon labeled “Shortcut to Tension Test"
5. Install the specimen in the upper grip of the machine. Make sure that the gripping surfaces make full contact with the thicker part of the specimen.
6. While holding the lower grip open, move the lower crosshead until you can grip the
specimen in a similar fashion with the lower grip. The specimen should be centered between the grips. **Note:** Stop the machine before closing the lower grip.

7. Install the extensometer on the specimen. Your TA will help you to do this. **Note:** The extensometers are rather fragile and very expensive instruments. Please handle them with extreme care.

8. After installing the extensometer, press the “reset” switch on the amplifier.

9. While making sure that the lower grip is open, verify that the load readout on the panel meter is zero. Adjust the zero control if necessary.

10. Close the lower grip. Make sure that the load has not changed by more than one or two pounds. Do not touch the load zero knob during the rest of the experiment.

11. Remove the extensometer pin. Zero the output of the extensometer using the “trim” knob on the amplifier.

12. Set the speed of the lower crosshead at 0.1 in/min. Make sure that the speed selector switch is pointing towards the digital readout (away from the speed control knob).

13. Start the data acquisition system by clicking on the white arrow in the upper left corner of the screen. Give a file name where the data will be stored. File name convention should be XXXhot.xls or XXXcold.xls, depending on the material type; where XXX are the student’s initials.

14. Press the button labeled **DOWN**. This starts the test.

15. When the strain reaches about 0.01 stop the ATS machine (but not the data acquisition system) and unload the specimen (by pressing the button labeled **UP** until the load is less than 100. Stop the machine at that point.

16. Press the **DOWN** button to resume the test.

17. When the strain reaches 0.1 or the specimen starts to neck, stop the machine and remove the extensometer from the specimen. Replace the pin in the extensometer.

18. Press **DOWN** to resume the test.

19. Continue the test until the specimen fractures. At that point stop the machine and the data acquisition process (Click on the large stop icon on the lower right part of the screen. **Never press the small stop icon at the top of the screen.** This aborts the program without saving the data).

20. Verify that your data has been saved using Excel.

21. Clean up the work area.

**Report Guidelines:**

Your lab report must include the following (use U.S. customary units in your report). The first two items are for your specimen only. For item three through eight, use the mean (and report standard deviation) values for the specimens in your lab group. Please share the material properties that you calculate in items #3 and #4 for your specimen with your lab group, so that no one has to calculate the values for all of the specimens. You will make arrangements through your TAs to share your data, using Box; please do so in a timely manner so everyone has...
adequate time to prepare the lab report. Failure to share the calculated values for your specimen by the due date will result in a 10% penalty. You should receive an invitation to collaborate from your TA within 24 hours of performing the lab. Email your TA if you do not receive an email.

1. A stress-strain plot for strain up to 5% (0.05) using the extensometer data. In this plot, indicate the relevant material properties of your specimen such as the proportional limit, the upper yield stress, the lower yield stress, the 0.2% offset yield stress and Young’s modulus. (Depending on which specimen you have and the shape of your stress-strain curve, you will need to determine which properties pertain to your specimen. See Figures 1 and 2.)

2. A stress-strain plot for the complete experiment using the load-displacement (LVDT) data. Indicate the ultimate stress on this plot.

3. From the extensometer data, report Young’s modulus during loading, Young’s modulus during unloading, stress at the proportional limit and appropriate yield stress(es) for each specimen type.

4. From the LVDT data, report Young’s modulus during loading, appropriate yield stress(es), and ultimate stress for each specimen type.

5. Compare the material properties of hot and cold rolled steel.

6. Compare the Young's moduli measured during initial loading and unloading for each specimen type (i.e. hot and cold rolled) using the extensometer data.

7. For both specimen types (i.e. hot and cold rolled), compare the initial Young's moduli and yield stresses obtained using the extensometer data with those obtained using the displacement transducer (LVDT) data. Comment on the results and try to explain any differences.

8. Compare the mean values for Young's modulus and yield stress you found for each specimen type with those listed in an engineering handbook (cite the book in your references).
Appendix A

Equipment

• ATS Testing Machine, Axial Extensometer
• Personal Computer Data Acquisition Hardware/Software
• DC-LVDT
Experiment 1  
Topic: Uniaxial Tension  
Pre-Lab Quiz  
Score: ______/40

Part I

Please match the correct name or description of points or symbols on Figure 1. (a – e)

1. The maximum or ultimate stress _______ a.) Point A
2. The work-hardening range since the stress increases with increasing straining _______
3. Yield stress or stress at the yield point _______ c.) \( \sigma_y \)
4. The proportional limit ________ d.) The slope of line OA, E
5. Young’s Modulus or modulus of elasticity _______ e.) The range between A and D

Figure 1: Stress-strain curve typical of some metals
Part 2

Please match the correct name or description of points or symbols on Figure 2. (f–i)

![Stress-strain curve](image)

**Figure 2:** Stress-strain curve typical of mild steel

6. The lower yield stress ________ f.) *Point A* \( (\sigma_{yu}) \)

7. Straining beyond the stress point causes the material to *strain harden* ________ g.) *Point B* \( (\sigma_{yt}) \)

8. The stress remains approximately constant ________ h.) *Point C*

9. The upper yield stress ________ i.) *Between points B and C*

Part 3

10. What two types of steel will be tested?

11. Will you need to share your data with your classmates?
Part 4

Please match the correct item to complete steps of the experiment procedure. (j – q)

12. Install the specimen in the upper grip of the machine. _________

13. While holding the lower grip open, move the lower crosshead until you can grip the specimen in a similar fashion with the lower grip. _______

14. Install the extensometer on the specimen. Your TA will help you do this. _________

15. After installing the extensometer, ________

16. ________, verify that the load readout on the panel meter is zero. Adjust the zero control if necessary.

17. Close the lower grip. _______. Zero the output of the extensometer using the “trim” knob on the amplifier.

18. Start the data acquisition system. _________

19. Continue the test until the specimen fractures. At that point stop the machine and the data acquisition process __________

j.) Make sure that the gripping surfaces make full contact with the thicker part of the specimen.

k.) press the “reset” switch on the amplifier.

l.) Note: The extensometers are rather fragile and very expensive instruments. Please handle them with extreme care.

m.) Note: Stop the machine before closing the lower grip.

n.) (Click on the large stop icon on the lower right part of the screen. Never press the small stop icon at the top of the screen. This aborts the program without saving the data.)

o.) Make sure that the load has not changed by more than one or two pounds. Do not touch the load zero knob during the rest of the experiment.

p.) While making sure that the lower grip is open.

q.) by clicking on the white arrow in the upper left corner of the screen. Give a file name where the data will be stored.