ENGR 2320 Mechanics of Solids and Structures
Due Friday 3/16/18 at 5pm

The Totally Terrific Tension Test

This is a two or three person assignment. Each team will submit a single report and receive a common grade.

Objectives

1. Experimentally determine material properties and states of strain/stress and factors of safety based upon uni-axial tension tests.
2. Write a MATLAB script that will perform required calculations.

Part I: Tension Tests. Determine material properties from test measurements.

You will perform three uni-axial tension tests using the Instron 5582 Universal Tester in the Material Science Lab. You will record the data needed to create a stress-strain curves from which you will determine material properties. The tension force is measured by a load cell in the machine. The deformation of the specimen will be measured by the cross-head, an extensometer, or strain gages.

Manuals for the tester machine and the control software (Bluehill) are on the top of the interface computer. A copy of the guide to the tester is in the course folder. Read this first. The ninjas are familiar with this system and are available for consultation.

**Carefully review and then follow all safety precautions. Wear eye protection at all times when using the tester.*

**Please keep the area around the Instron machine neat and clean. Discard related waste and return the strain gage hardware (including the power supply and all cables) to the table in front of AC 427.*

Test Specimens

Aluminum and steel ‘dog bone’ test specimens are available on the table outside of AC427. You may need to remove the rust from the steel specimens using steel wool and/or sandpaper. You should also gently sand the edges of the specimens (why?).

Test Directions

a) The 0-6mm grips will be used for these tests. Make sure the safety wires are attached to the pins. Vertically align a dogbone specimen in the grips. Tighten the grips very firmly so the specimen doesn’t slip.
b) Double click the Bluehill icon on the desktop. A ‘test method’ is an instruction file that contains all of the test parameters. Create new method file or copy and modify the one in the course folder.
c) You will be prompted to “Create a New Sample.” Give your files a logical name and save the files in an easily-accessible location.

d) Check that there are two buttons labeled, ‘Rest Gauge Length’ and ‘Balance Load’ at the top of the screen. To add/change the two buttons click on the ‘Control Panel’ icon in the upper left corner.
e) Go through the ‘Method’ tab and input the dimensions of your test sample under the ‘Specimen’ heading. The dog bones may be of different sizes. Example values, width = 13.2 mm, thickness = 1.5 mm, and gage length = 57 mm (length of straight section or, if using the extensometer, gage length of extensometer).
f) Verify the test control settings in the ‘Method’ tab (maroon) under ‘Control’

- <u>Pretest</u>. A 300N preload is used to take up any slack in the specimen. Preload: control mode = extension, Rate = 10 mm/min, Channel = load, Value = 300N
- <u>Test</u>. Set the cross-head speed (strain/displacement rate). This is separated into two sections. In the first section, the rate of Ramp 1 is 1 mm/min. This will encompass the elastic and a portion of the plastic region. There is a changeover at an extension of 5 mm to Ramp 2. The rate is increased rate of 7 mm/min which covers the remainder of the plastic region. Control mode = extension. You can also change the rate during the test through the box in the blue section of the window.
- <u>End of Test</u>. Use the criteria, ‘% peak load=load drops by 30%. This should allow the specimen to rupture/fracture and then stop the test. Use the ‘jog up’ button to fracture the specimen if necessary.
- <u>Data</u>. Manual. Criteria 1. Manual = 50 ms (or 200 data points/sec). This should save enough data points to generate a smooth curve.
- <u>Strain</u>. Set this to Extension for the cross-head and Strain 1 for the extensometer. *Important:* the extensometer must be removed before fracture to prevent damage. The ‘remove during test’ box should be checked. The removal point is set at 0.058 mm/mm strain. Use the ‘Pause test but suspend data capture’ option. Remove the extensometer by pinching the black knobs and sliding the clips off.
- <u>Raw Data</u>. Save at least Time, Extension, Load, Tensile Stress, Tensile Strain

g) Under the ‘Reports’ tab, verify that the results will be exported and the raw data will be saved as a .csv file.
h) Click the ‘Balance Loads’ and ‘Reset Gauge Length’ buttons to initialize the test and, if using the extensometer, calibrate it by clicking the ‘Strain 1 setup’ button at the top right.
i) Make sure the protective shield is in place. Under the ‘Test’ tab, click the ‘Start’ button (right hand side) to begin the test.
j) After the test when removing the dog bone, *do not over loosen the clamps*. You may have to pry or knock the clamps apart.

Test Descriptions
Test 1: The first test is to be done without the extensometer or the strain gages. There will be enough data to make a stress-strain curve to fracture/rupture.
Test 2: For the second test, use the extensometer to measure displacement/strain. First, place the specimen in the grips. Then attach the extensometer-pinch the black knobs and carefully center the knife edges on the specimen. When you balance the loads and reset the gauge length, check that Strain 1 (the extensometer) is also zeroed. Remember, to

prevent damage to the extensometer, *it must be removed before the specimen fractures*. Verify under the 'Method' and 'Strain' tabs that Strain 1 is selected. Set the test to stop at a given strain value (*e.g*., 0.058 mm/mm) and then resume after the extensometer has been removed. There may be a slight discontinuity in the measurement as strain is now being determined from the cross-head.

Test 3: In the third test, use both strain gages and the extensometer to measure strain. You can load the strain gage data acquisition software onto your laptop. An install file and manuals are in the course folder.

Read through the references in the course folder. Study the directions for bonding gages to specimens. Use acetone or alcohol (next to sink in Mat Sci lab) to clean the specimens. Use superglue gel (cyanoacrylate) as the adhesive. *Do not lose the green screwdriver that goes with the DAQ system. It's the only one left.*

Attach a single strain gage rosette to the dogbone. Leave room for the extensometer. Do not allow it to contact the strain gage wires. Align the rosette so that one gage is aligned with the direction of the load and a second is transverse (perpendicular) to the direction of the load. Note, that the strain gages have a limited range and will not make measurements over the entire plastic range.

Determining Material Properties

There are three sources of strain/displacement data: cross-head, extensometer, and strain gages. You will be able to create a complete (to near-fracture) stress-strain plot from the cross-head data. You can make a complete stress-strain plot in the elastic region and a partial plot in the plastic region from the extensometer and strain gage data. From each strain-measurement data type, make a stress-strain plot and determine,

1) Young's modulus
2) proportional limit (straight line estimate)
3) yield stress (strength) based on a 0.05% and on a 0.2% offset. You will need to account for the preload which creates a constant offset that needs to be removed
4) modulus of resilience (area under elastic portion of stress/strain curve)
5) Poisson's ratio (strain gage data only)
6) Shear modulus (strain gage data only)

From the cross-head-measurement-based stress-strain plot, determine,

7) ultimate stress (strength)
8) fracture stress (strength)
9) modulus of toughness (area under entire stress/strain curve, note that it is hard to find published values for comparison)

You will need to use a numerical integration routine to calculate the area under the stress/strain curve.

Part II: Stress Analysis. From strain measurements, determine the state of stress and factor of safety as compared to the Yield Strength.

Write a MATLAB script which takes as input:

- three angles which orient the strain gages relative to the horizontal axis
- measurements from the three strain gages
-Young's modulus, Poisson ratio, and yield strength

The script should calculate the
-state of strain
-state of stress
-corresponding principal stresses and maximum (in-plane and absolute) shear stresses
-corresponding maximum effective (von Mises) stress
-factor of safety of maximum effective stress with respect to yield strength

Questions:
1) Explain the shape of the dogbone specimen.
2) Compare your material properties to published values.
3) How do the axial strain gage measurements compare to the extensometer and cross-head measurements? Explain the discrepancies.
4) What are the values of stress, load, strain, and displacement at the elastic yield (0.2%) point?
5) How does the maximum effective stress compare to the normal and principal stresses?
6) Compare the direct measurements of the strain gage at 45^o to predicted strain values based upon the strain transformation of the axial and horizontal strain gage measurements.
7) Analyze sensitivity to gage alignment. For example, if the axial gage is actually at 92^o with respect to the horizontal, how is the predicted value for a 45^o gage affected?
8) Explain why the specimens fractured along the plane that they did.

Deliverables:
Summarize your work in a written report which includes the following:
1) Description of how tension tests were performed. Indicate relevant test parameters. A useful report both summarizes what was done as well as explains why things where done.
2) Plots (or portions of) of stress-strain and load-extension for all tests. All plots should have captions which both describe the plot and summarize the point of the plot. What amount of strain and displacement did your specimens undergo at yield?
3) Table of determined material properties with comparison to published values. What material are your specimens?
4) Answers to the questions above.
5) MATLAB script for strain-to-factor of safety calculation. Example demonstration.
6) A short discussion of a topic that you found to be especially interesting or something you were surprised to learn from the tests.
7) Save the wires from your rosette. Put them on the supply table. We can reuse them later.