ESc 22 MECHANICS II: MATERIAL SCIENCE

LAB 4: TENSILE TESTING OF METALS AND POLYMERS

INTRODUCTION

We have learned about the elastic and plastic deformation in materials, about a stress-strain curve for tensile and compressive testing, and that many materials have an elastic region. Today we will investigate elasticity and plasticity by gathering experimental data during a uniaxial tensile test to calculate Young's modulus, yield and ultimate strength, and ductility for two different types of materials. You must make good observations and be detailed in your data acquisition and descriptions. The results of this lab will be reported in a laboratory report due as stated by your Instructor.

FOR YOUR LAB NOTEBOOK

1. Split up into groups of about three people. Each group should select a unique specimen.

Specimen	Color
brass	yellowish metal
aluminum	light gray metal
steel	dark gray metal

Specimen	Color
polycarbonate (Lexan)	translucent plastic
acrylic (Plexiglas)	clear plastic
nylon	opaque plastic

2. Sketch each specimen in your lab notebook. Measure important dimensions, i.e., the gage length L_0 between the threaded portions and the specimen diameter D_0, and record them on your sketch. Use the micrometer for a precise measurement of the diameter. Get sketches and/or dimensions from the other groups as required.

3. Examine the mechanical extensometer on the table and observe the movement of the slide arm and the three dials. Hold the extensometer closed and measure the distance between the two knife edges (it should be about 2" long). Sketch the dial. The extensometer readings of ΔL are used to calculate values of strain in the elastic and yielding regions. Each mark on the perimeter of the dial is equal to 0.0001".

4. Take your specimen to the tensile test machine. Assign one person to the computer, one to insert and remove the specimen and to read values off the extensometer, and one to record the data.

5. Thread each end of the specimen into the grips on the testing machine. Thread the bottom end first and then move the crosshead up to a location convenient to place thread the top end into the grip. Your Instructor will zero the crosshead and apply a small load of about 40 N to remove any "slack" in the fixturing. Follow instructions carefully to maintain a safe lab environment, and wear safety glasses.

6. Now carefully hold the extensometer closed and fix it onto the gauge section of the specimen prior to the start of the tensile test. Do not force the tightening of the screws: you will be able to sense when the screws are snug and in place. With the polymer specimens, be especially careful not to tighten the screws of the extensometer too tightly so as to create notches in your specimen that will result in stress-concentrated failures at those points. Prepare a table of load F (N) vs. extensometer Δl (in, which you will convert to mm). During the actual test, the person on the computer will call out "mark" every 200 N for the polymer specimens and every 400 N for the metal specimen, at which time the person monitoring the extensometer should call out the value. The person recording the table should thus have pre-prepared a table in which to enter these extensometer values. These data will be acquired only in the elastic region so as not to damage the extensometer. The Instructor will tell you when to remove the extensometer before substantial plasticity and/or failure.

7. When you are ready, hit the green arrow button, and enter the value for the diameter of the specimen.

8. Record values from the extensometer as described.

9. When you start to see the curve taper off and leave the elastic region, remove the extensometer quickly and carefully. Hold the extensometer closed when you are removing the screws.

10. Observe the specimen to fracture. Up to this point, the load on the specimen was being applied at a rate of 0.02"/min. For the metal specimens, you may increase the rate to 0.2"/min.

11. If and when your specimen has fractured, remove the top part of your specimen from the top grip, then return the crosshead to zero. Remove the bottom part of your specimen from the bottom grip. If your specimen did not fracture but extended for a long period of time, follow instructions on removing the specimen from the tensile test machine.

12. Examine the location of fracture, and sketch it in your lab notebook.

13. Measure the final diameter D_f of your specimen at the point of fracture if appicable. Measure the final length L_f of your specimen between the threaded portions.

14. Convert your data to stress and strain from

$$\sigma = \frac{F}{A_0} \qquad\qquad \varepsilon = \frac{\Delta L}{L_0}$$

15. Obtain these data for the other specimens from the other groups.

16. Sketch the stress-strain curve using the measurements from the extensometer, labeling the axes and units correctly. Estimate the Young's modulus E.

FOR YOUR LAB REPORT

Your lab report is a flowing, written document. It should tell the story of what you did, why you did it, what were the results, whether the results were reasonable and expected or surprising, and what is the significance of what you did.

Title. Provide your own descriptive title of this activity.

Abstract. Write one paragraph of a maximum of 250 words summarizing the objective of the experiment and the results.

Symbols. Provide a list of symbols and their definitions after the Abstract.

Introduction. Provide background to this experiment, including, but not limited to, the material you are examining, the reason for the experiment, the actual applications of the material tested. Capture the attention of the reader by showing the importance of and interest in this experiment.

Materials and Methods. Describe the specimens, test machine, experimental protocol, data acquisition, data reduction, and data analysis and presentation in dry detail.

Results. Report all data and findings in this section. Recall that the details of how the following parameters were computed belongs in the Materials and Methods section and that the Results section contains only the results of these calculations:

- Using the data collected from the load-frame apparatus and computer, plot the stress-strain curve for the specimens tested. You may plot both curves on the same graph, clearly identifying and labeling each.
- Determine the approximate yield strength at a strain offset of 0.2%, the ultimate strength, and the fracture strength for each specimen. Make a table summarizing these results.

- Add the extensometer measurements onto your plots of the stress-strain curves for each your specimens.
- Calculate Young's modulus for each specimen from the crosshead and the extensometer data, and describe your calculations.
- Calculate Poisson's ratio for each specimen using the longitudinal and transverse strains at fracture.
- Calculate the ductility of each specimen by the percent elongation and the reduction in area method.
- Calculate the approximate value of the resilience of each specimen and explain your calculations.
- Calculate the approximate value of the toughness of each specimen and explain your calculations.
- Calculate the true stress at fracture of each specimen.

Discussion. Describe any factors that may have influenced your experiment, and suggest improvements. Comment on the data acquisition process. Incorporate the following into the Discussion section:

- Compare E from the extensometer data and the computer data for all of your specimens. Which one is more accurate and why?
- Compare E between the metals and between the polymers, and the elastic-plastic behavior between the metals and polymers.
- How would E change if the tensile test was run at 0ºC and at 100ºC instead of room temperature 25ºC?
- Compare the experimentally determined values of E for your four materials and compare them to book values. Be sure to reference the source of your comparison.
- Which calculation of ductility is more accurate and why? Or, are they both useful in describing ductility? When would you use one or the other?
- Compare and discuss the resilience of all specimens.
- Compare and discuss the toughness of all specimens.
- Why is it sometimes more useful and meaningful to know the true stress value rather than the engineering stress value?
- Did you observe strain rate sensitivity in either of your two specimens? What do you think would happen if your specimen was tested at a higher rate?

Conclusion. Summarize key findings in this section along with comparisons to the work of others.

References. List references to books,[1] journal papers,[2] and web sites[3] using their proper bibliographic formats with superscripted citations as shown.

1. Rapoff AJ, Zdeblick TA. Biomechanical models of the cervical spine. In: Yoganandan N, Pintar FA, Larson SJ, Sances A Jr, eds. Frontiers in head and neck trauma: clinical and biomechanical. IOS Press, 1998.
2. Rapoff AJ, Johnson WM, Handel J, Woo R. Interbody allograft in a skeletally immature spine model. *European Spine Journal* 2003;12(3):307-313.
3. Andrew Rapoff's Main Page. http://engineering.union.edu/~rapoffa. Accessed 26 January 2005.

Acknowledgments. List any collaborations you wish to acknowledge (e.g., your group members or someone providing technical assistance) or any resources that were provided to you in accomplishing this experiment and lab report.

Formatting Requirements. Use the following format: Times New Roman 12 point font, double line spacing, and 1" margins all around. Symbols are italicized; numbers and units are not You will be graded on quality of content, discussion, organization, proofreading, and intellectual creativity.