ME 354, MECHANICS OF MATERIALS LABORATORY

MECHANICAL PROPERTIES AND PERFORMANCE OF MATERIALS: TENSILE TESTING*

01 January 2000 / mgj

PURPOSE

The purpose of this exercise is to obtain a number of experimental results important for the characterization of the mechanical properties and performance of materials. The tensile test is a fundamental mechanical test for material properties which are used in engineering design, analysis of structures, and materials development.

EQUIPMENT

- Reduced gage section tensile test specimens of 6061-T6 aluminum
- Reduced gage section tensile test specimens of hot-rolled 1018 or A36 steel
- Reduced gage section tensile test specimens of polymethymethacrylate (PMMA(acrylic))
- Reduced gage section tensile test specimens of polycarbonate (Lexan™ (PC))
- Clip-on extensometer
- Tensile test machine with grips, controller, and data acquisition system
- Calipers

PROCEDURE

per ASTM E8M "Standard Test Methods of Tension Testing of Metallic Materials [Metric]"

For each material, perform the following steps.

- Measure the diameter of the gage section for each test specimen to 0.02 mm.
- Measure the marked gage length of the gage section (in this case 50.8 mm).
- Zero the force output (balance).
- Activate force protect (~500 N) on the test machine to prevent overloading the test specimen during installation.
- Install the one end of the tensile test specimen in the top grip of the test machine while the test machine is in displacement control.
- Install the other end of the tensile test specimen in the lower grip of the test machine.
- In displacement control adjust the actuator position of the test machine to achieve nearly zero force on the test specimen.
- Attach the extensometer to the gage section of the test specimen, centering it in the gage section. Zero the output from the strain conditioner.
- Deactivate force protect.
- Initiate the data acquisition and control program.
- Enter the correct file name and specimen information as required.
- Initiate the test sequence via the computer program.
- At maximum force (i.e. after some amount of necking in the gage section), only if necessary, remove the extensometer to avoid damage to the extensometer at fracture.
- Continue the test until test specimen fracture.
- Measure the smallest diameter of the gage section at the location of failure. Measure the final length between the marks which denoted the original gage length of the test specimen.

ANALYSIS

The analysis is conducted from the raw data [P, force (kN) vs. ΔL, change in length (mm)] which are available in either computer readable text files or on hard copy text files.

Plot or determine ALL of the following for ALL of the materials.

- Plot engineering stress ($\sigma \approx \frac{P}{A_o}$ MPa) versus engineering strain (use %, m/m or µm/m for $\varepsilon \approx \frac{\Delta L}{L_o}$)

- Determine the following from the engineering stress vs. engineering strain plots.
  - a) proportional limit stress, $\sigma_p = \sigma_o$
  - b) 0.2% offset yield stress, S_{yp}
  - c) ultimate tensile strength, S_{uts}
  - d) modulus of elasticity (by approximate formula ($E \approx \frac{\sigma_p}{\varepsilon_p}$) and/or numerical method (E=m from linear regression of σ vs ε))
  - e) modulus of resilience (by approximate formula ($U_r = \int_0^{\varepsilon_o} \sigma d\varepsilon \approx \frac{1}{2}\sigma_o \varepsilon_o$)and/or numerical method ($U_r = \int_0^{\varepsilon_o} \sigma d\varepsilon \approx \sum_{i=1}^{i=n @ \varepsilon_o} \left(\frac{\sigma_{i+1} + \sigma_i}{2}\right)(\varepsilon_{i+1} - \varepsilon_i)$))
  - f) modulus of toughness. (by approximate formula $U_T = \int_0^{\varepsilon_f} \sigma d\varepsilon \approx \frac{S_{uts} + \sigma_o}{2}\varepsilon_f$ and/or numerical method ($U_T = \int_0^{\varepsilon_f} \sigma d\varepsilon \approx \sum_{i=1}^{i=n @ \varepsilon_f} \left(\frac{\sigma_{i+1} + \sigma_i}{2}\right)(\varepsilon_{i+1} - \varepsilon_i)$)))

- From the diameter and length measurements, determine the following.
  - a) true fracture stress, $S_f^T = \frac{P_{\max}}{A_f}$
  - b) percent reduction in area, $\%RA = q = 100\frac{A_o - A_f}{A_o}$
  - c) percent elongation, $\%el = q = 100\frac{L_f - L_o}{L_o}$

Plot or determine ALL of the following for ONLY the aluminum alloy.

- Plot the true stress, s, versus true strain, e, curve along with the engineering stress, σ, versus engineering strain, ε, on the same graph from 0 to maximum force only. Determine the true stress at maximum force and the true uniform strain (i.e., true strain at maximum force, prior to onset of necking). (Note: $s = \sigma(1+\varepsilon)$ and $e = \ln(1+\varepsilon)$) for region of uniform strain.

- Construct a plot of log true stress versus log true strain and determine, using linear regression, the 'best' values of n and K (or H) for the approximate constitutive relation:

$$s = \mathrm{K}e^{\mathrm{n}} = \mathrm{H}e^{\mathrm{n}} \qquad (1)$$

where s is the true stress, e is the true plastic strain, K or H is the strength coefficient, n is the strain hardening exponent per ASTM E646 "Standard Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials."

- Add the plot of this constitutive approximation (i.e. calculate the stress using K, n, and measured strain) to the plots of measured true stress versus measured true strain and measured engineering stress versus measured engineering strain. Determine the percent error between the true stress calculated from the approximate constitutive relation (Eq. 1) and the measured true stress at measured true strain values of 0.1%, 1%, and 5%.

* REFERENCES

Annual Book or ASTM Standards, American Society for Testing and Materials, Vol. 3.01
E8 Standard Test Methods of Tension Testing of Metallic Materials
E8M Standard Test Methods of Tension Testing of Metallic Materials [Metric]

E646 Standard Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials

LABORATORY REPORT

1. Include the following information in the laboratory report.

	1018 (HR) or A36 steel	6061-T6 aluminum	PMMA (acrylic)	PC (polycarbonate)
proportional limit stress (MPa).........				
0.2 % offset yield strength (MPa).....			-	
ultimate tensile strength (MPa)........				
modulus of elasticity (GPa)......[AF]				
modulus of elasticity (GPa)......[NM]				
% difference......................................				
modulus of resilience (J/m^3)....[AF]				
modulus of resilience (J/m^3)....[NM]				
% difference......................................				
modulus of toughness (J/m^3)...[AF]				
modulus of toughness (J/m^3)...[NM]				
% difference......................................				
true fracture strength (MPa).............				
% reduction in area...........................				
% elongation.....................................				
true stress @ maximum force(MPa)	- - - - -		- - - - -	- - - - -
true uniform strain.............................	- - - - -		- - - - -	- - - - -
strain hardening exponent, n...........	- - - - -		- - - - -	- - - - -
strength coefficient, K (MPa)...........	- - - - -		- - - - -	- - - - -
true stress at 0.1% true strain(MPa)	- - - - -		- - - - -	- - - - -
$\sigma = K\varepsilon^n$ at 0.1% true strain (MPa)....	- - - - -		- - - - -	- - - - -
% difference......................................	- - - - -		- - - - -	- - - - -
true stress at 1% true strain (MPa)..	- - - - -		- - - - -	- - - - -
$\sigma = K\varepsilon^n$ at 1% true strain (MPa).......	- - - - -		- - - - -	- - - - -
% difference......................................	- - - - -		- - - - -	- - - - -
true stress at 5% true strain (MPa)..	- - - - -		- - - - -	- - - - -
$\sigma = K\varepsilon^n$ at 5% true strain (MPa).......	- - - - -		- - - - -	- - - - -
% difference......................................	- - - - -		- - - - -	- - - - -

Note: AF = approximate formula. NM = numerical method (least squares or numerical integration).

2. Include the following information in the laboratory report.
   a. Engineering stress vs. engineering strain for all materials.
   b. Engineering stress vs. engineering strain and true stress vs. true strain on the same graph for the alumimum alloy.
   c. Log-log plot of true stress vs. true strain along with the curve fit on the same graph for the aluminum alloy
   e. Eng. stress vs. eng. strain and true stress vs. true strain with calculated stress vs. strain from Eq. 1 for the aluminum alloy on the same graph
   f. Compare results of these tests for each material to 'book' values from a source such as the ASM Metals Handbook. Comment on any differences.
   g. Compare fracture surface appearances and mechanical properties for each material (metals & polymers). Comment on the brittle/ductile behaviour of each.
3. Include the following information in the appendix of the laboratory report. THIS MAY NOT BE ALL THAT IS NECESSARY (i.e., don't limit yourself to this list.)
   a. Original data sheets and/or printouts
   b. All supporting calculations. Include sample calculations if using a spread sheet program. DO NOT INCLUDE ALL TABULATED RAW OR CALCULATED DATA.

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DATA SHEET

01 January 2000 / mgj

NAME_____________________________________**DATE**____________

LABORATORY PARTNER NAMES____

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EQUIPMENT IDENTIFICATION_____________________________________

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Aluminium metal

Initial (units)	
D_o ( )	
L_o ( )	
Final (units)	
D_f ( )	
L_f ( )	
Observed Maximum Force ( )	
Observed Fracture Force ( )	

Steel metal

Initial (units)	
D_o ( )	
L_o ( )	
Final (units)	
D_f ( )	
L_f ( )	
Observed Maximum Force ( )	
Observed Fracture Force ( )	

PMMA (acrylic) polymer

Initial (units)	
D_o ( )	
L_o ( )	
Final (units)	
D_f ( )	
L_f ( )	
Observed Maximum Force ( )	
Observed Fracture Force ( )	

Polycarbonate polymer

Initial (units)	
D_o ( )	
L_o ( )	
Final (units)	
D_f ( )	
L_f ( )	
Observed Maximum Force ( )	
Observed Fracture Force ( )	