EN400

LAB #6

MATERIALS AND MATERIALS TESTING

Instructions

1. This lab is conducted in the Mechanical Engineering Materials Lab, on the ground floor of Rickover Hall, Ri-025.

2. Prior to arriving, read through the lab procedure so that you are familiar with the steps necessary to complete the lab.

3. Bring this handout and a calculator to the lab.

4. The lab is to be performed as a whole class. Your instructor will specify whether each small lab group or each individual must submit the completed lab.

5. Follow the stages of the lab in consecutive order. The lab follows a logical thought pattern and jumping ahead without completing the intervening theory questions will limit your understanding of the concepts covered.

6. For full credit, all work must be shown on the lab. Show generalized equations, substitution of numbers, units, and final answers.

Student Information:

Name(s): ______________________________________________________

Section: _________

Date: __________

Note: This lab does not have a pre-lab.
Part 1: Material Properties

Strength

Recall that the strength of a material is defined as “a measure of a material's ability to resist deformation and maintain its shape.”

1. This is quantified in terms of yield stress ($\sigma_y$) or ultimate tensile stress ($\sigma_{UTS}$). Sketch a stress/strain diagram for a material showing these 2 quantities.

2. During the Instron machine tensile test demonstration, the output consists of a plot of force (lb) against elongation (in). These values are converted into stress and strain.

   a. Give the equation that links the force, $F$ (lb), to the stress, $\sigma$ (psi), it is creating in a material.

   b. Give the equation that links elongation, $e$ (in), to the strain, $\varepsilon$ (in/in), created in a material.

3. The standard sample used in the Instron machine is drawn in Figure 1. It consists of a cylinder exactly 2 inches long with a cylindrical diameter of 0.505 inches.

   ![Figure 1 The Standard Material Sample](image)

   **Figure 1** The Standard Material Sample
4. Use the specimen’s dimensions, the force/elongation plots observed in class and equations in problem 2. to complete the following.

<table>
<thead>
<tr>
<th>Material:</th>
<th>1018 Steel</th>
<th>1045 Steel</th>
<th>2024 Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force at which material yields (lb)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield Stress, ( \sigma_y ) (psi)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum force (lb)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimate Tensile Stress, ( \sigma_{UTS} ) (psi)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. From this data, which material has the highest \( \sigma_{UTS} \)? ___________________

Which material has the lowest \( \sigma_{UTS} \)? ____________________________

**Ductility**

Ductility is defined as follows: “a measure of a materials ability to deform before failure.”

It can be quantified by reading the value of strain at the fracture point (\( \varepsilon_f \)) or by calculating the reduction of cross-sectional area at fracture as a percentage of the original cross-sectional area. To enable the last calculation to be performed the diameters of the standard sample after fracture needs to be known.

6. Using the above information and lab data, complete the following:

<table>
<thead>
<tr>
<th>Material:</th>
<th>1018 Steel</th>
<th>1045 Steel</th>
<th>2024 Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter at Fracture (in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at Fracture (in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain at Fracture (in/in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final X-Sectional Area, ( A_f ) (in(^2))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss in X-Section Area, ( A_l ) (in(^2))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Reduction in Cross-Sec Area</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. From this data, which material is the most ductile? ______________________________

Which material is the least ductile? ___________________________________________
Toughness

Toughness is defined as: “.....a measure of a material’s ability to absorb energy.” In fact, there are two measurements of toughness.

8. Material toughness can be found from force/elongation diagrams.
   a. How is it calculated? ________________________________________________

  __________________________________________________________________

   b. What are the units of toughness when measured this way? ______________

Toughness can also be measured from a Charpy V-notch test, shown in Figure 2. This is a test that measures the energy absorbed by a material when fractured by a sudden impact.

Impact toughness is determined from finding the difference in potential energy before and after the hammer fractures the material. The Charpy V-notch test will be demonstrated in lab.

The weight of Charpy Apparatus hammer is 55 lb. The initial height of the hammer is 57.625 in.

Figure 2  Charpy V-notch Test Apparatus

9. Using the potential energy equation (PE = m·g·h), complete the table.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1018 Steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1045 Steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold 1018 Steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024 Aluminum</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
10. From this data, which material has the highest impact toughness? ____________________

Which material has the lowest impact toughness? _______________________________

11. Sketch the impact toughness against temperature curve for a regular steel. Make sure you label the axis correctly. Show where the material is behaving with brittle behavior and ductile behavior and indicate the transition temperature.

12. Of the 2 measures of toughness:
   a. Which measurement would be most relevant to a submarine hull as it slowly increases its depth? ________________________________________________
   b. Which measurement would be most relevant to a submarine hull when subjected to an underwater explosion? ________________________________

**Fatigue Testing**

13. What is the purpose of fatigue testing? ________________________________________

________________________________________

14. In the space below, sketch the plot obtained from a fatigue test at a number of different stress levels for steel and aluminum. Ensure you label the axis correctly and show any significant points.
15. Using the information in this sketch, what advantage does steel have over aluminum as a structural material?________________________________________________________
_______________________________________________________________________

Hardness

Hardness is defined as “a measure of a material’s ability to resist indentation, abrasion & wear”

16. How is the hardness of a material measured? ________________________________
_______________________________________________________________________

17. How is this related to the strength of a material? __________________________
_______________________________________________________________________

As a class, we will measure the hardness of 1018 and 1045 steel Charpy samples, using a Rockwell Indenter. To ensure an accurate hardness measurement, we must maintain a minimum spacing of 3 ball diameters from all sample edges and previous indents (this prevents our measurements from being influenced by edge effects and prior strain hardening).

18. Complete the table below. Estimate $\sigma_{UTS}$ using the hardness-to-strength conversion chart in the lab.

<table>
<thead>
<tr>
<th></th>
<th>Hardness Readings: Rockwell Scale</th>
<th>Average Hardness Readings</th>
<th>Approximate $\sigma_{UTS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1018 Steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1045 Steel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

19. Compare your results for $\sigma_{UTS}$ with those obtained from the tensile test portion of the lab.
Part 2: Non-Destructive Testing

20. For the following non-destructive testing techniques, describe the type of material flaws and faults that they can find and one operational disadvantage they incur.

<table>
<thead>
<tr>
<th>Non-Destructive Testing</th>
<th>Material Flaws Detected</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiographic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eddy Current</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasonic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetic Particle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual / Dye Penetrant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 3: 3-D Printing

21. List two advantages of 3-D fabrication techniques over traditional (subtractive) fabrication methods.
22. **Fused Filament Fabrication (FFF)**. Describe, in your own words, the physical methods and mechanisms by which this fabrication technique produces a 3-D part.

23. **Stereolithography (SLA)**. Describe, in your own words, the physical methods and mechanisms by which this fabrication technique produces a 3-D part.

24. **Laser Powder Bed Fusion (L-PBF)**. Describe, in your own words, the physical methods and mechanisms by which this fabrication technique produces a 3-D part.