Stress-Strain Analysis

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Objectives

Stress-strain analysis of a material is one way to determine many of its physical properties. With the information gained through much analysis, one can predict how a part will react when placed under various working loads.
The major objectives are:

(1) Understand the basic process of deformation due to tensile loading
(2) Characterize the physical properties of various metals from their stress-strain curves
(3) Determine how annealing a metal affects its physical properties
(4) Gain experience designing an experiment to gather necessary data using the available apparatus (this lab manual will provide you only with general guidelines on how to operate the equipment. There is also a user manual provided by the manufacturer of the equipment in the lab that is very useful, along with some tutorial CDs).

Equipment

The available axial loading system consists of a PASCO AP-8216 Stress Strain Apparatus, a PASCO CI-6746 Force Sensor and a PASCO CI-6538 Rotary Motion Sensor (www.pasco.com). The combined system gathers the necessary data to analyze stress strain behavior of material samples using the accompanying software.

The furnace used for annealing is a Thermolyne 47900, which produces heated environments up to 1208°C. It is located in Room 326 Keck.

Properties of Various Samples

Note: Since you are "creating your own experiment," it is VERY important that you document every step of your work in your lab notebook.

1. Get Started.
   Plug in the apparatus (there is no on/off switch) and turn on the accompanying computer. Double-click the "DataStudio" icon, and select "create experiment".
2. Set Start/Stop Parameters.
   It's important that the forces applied to the PASCO Force sensor not exceed the limit of the components within the sensor. Click the "Setup" button near the top of the

screen, and within the experiment setup window click “options”. In the sampling options window, go to the delayed start tab. Select “Data measurement” with “Force, push Positive” as the limiting parameter. Set the value so that recording begins when the Force is above 1 N. Next go to the Automatic Stop tab in the sampling options window. Again select “Data measurement” with “Force, push positive” as the limiting parameter. Set the limit at 45N. Take care to watch the software during any testing so that you can stop cranking immediately after the software stops taking data (when the force registered reaches your set limit of 45N).

3. Familiarize Yourself with the Program and Apparatus.
   - Learn how to load and operate the testing apparatus (the user manual is a good place to start).
   - Determine what measurements the program can extract from the testing apparatus.
   - Explore the various ways to manipulate data provided by the program (creating graphs, determining slopes, calculating functions of measured properties).
4. Obtain stress strain curves for various materials.
   For at least 3 of the materials provided, plot the stress-strain curve. From these curves, determine: Young’s Modulus, .2% Yield Stress, Ultimate Tensile Stress and Fracture Stress for each of the materials. For one of those 3 materials, test 2 more samples (a total of 3 samples of that material type) and examine the repeatability of the results. Some things to take into consideration when determining how to extract the necessary data:
   - The extension of the samples can be determined from the angular rotation of the knob by manually measuring the relationship between them.
   - As you test samples, the tensile force will cause the samples to stretch. However, the applied force also causes the apparatus platform and the force sensor to bend. The displacement being calculated by the software will be the combination of the sample stretching and the bending of the rest of the apparatus. Regardless of how the sample stretches, the bending within the apparatus is constant for a given force. You can measure this deformation directly by using the calibration bar, which does not stretch significantly.
   - The force measured by the force sensor is applied by a moment arm. The force acting on the sample being pulled not equal to the force measured by the sensor, but rather related according to the physics of how levers work and the distance from the pivot to the places where the forces act.
5. Analysis/Conclusions
   Compare the values found for Young’s Modulus, .2% Yield Stress, Ultimate Tensile Stress and Fracture Stress to typical values for such materials. Also compare the values between materials (ie, brass has a much greater UTS than steel). For the material that was tested 3 times, determine the consistency of results (justify mathematically). Discuss all findings.

Effects of Annealing

1. Data Collection.
   Implement your designed experiment from prelab question 4. Make sure to find the Young's Modulus, .2% Yield Stress, Ultimate Tensile Stress and Fracture Stress for all samples tested.
2. Analysis/Conclusions.
   Fully examine the effect of time and temperature on annealing. Provide both quantitative and qualitative arguments.
3. Hypothesis.
   Test one of the pre-annealed steel samples provided by Pasco. Given your conclusions about how annealing time and temperature affect the properties of steel, hypothesize as best you can the time and temperature at which the sample was annealed. Justify your answer.

Pre-lab Questions

1. Give a brief physical description of stress, and strain, including relevant equations.

2. Draw a typical stress strain curve for a metal specimen that underwent tensile loading until fracture. Label and describe the different stages of deformation.

3. Define each of the following terms. Also describe how you can determine each of them from a stress-strain graph: (include diagrams if useful)

   a) Young's Modulus
   b) .2% Yield Stress
   c) Ultimate Tensile Stress
   d) Fracture Stress

4. Research some typical annealing processes for steel. Using what you've learned, design an experiment that will answer the following questions: (keep all experimental procedures within the realm of treatments that produce desirable materials)

   a) What changes in physical properties are witnessed in a metal after annealing?
   b) How does the length of time annealed affect these properties?
   c) How does the annealing temperature affect these properties?