Sichuan University - Pittsburgh Institute

ME 1042

Mechanics/Materials
Lab

Uniaxial Tension Test of Materials

Revised November
2020

Mechanical Engineering Department

Goal: To determine the Young's Modulus, yield stress, ultimate tensile strength, ductility and toughness of aluminum and cast iron.

Equipment Needed:
Tensile Test Machine
Extensometer
Micrometer
Aluminum 6063 rods
HT 150 Cast Iron rods

1 Introduction and Basic Theory

The determination of stress-strain relationships is of fundamental importance to understanding material behavior. In this experiment, a tensile test machine will be used to apply a known stress and to measure the resulting strain for a series of metal samples. A stress-strain profile can then be produced to investigate elastic and plastic material properties.

1.1 *Uniaxial Loading*

When a rod of uniform cross-sectional area is suspended from a supported end and a load is applied, as shown in Figure 1, the rod will elongate. The engineering stress (σ) associated to the applied load can be calculated based on the following relationship

$$\sigma = \frac{P}{A}$$

where P is the applied load and A is the original cross-sectional area of the rod.

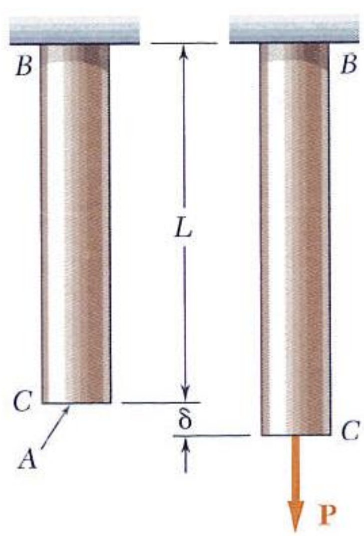

Figure 1: A rod under axial tension.

Uniaxial Tension Test

The elongation of the rod under the applied load is defined as deformation (δ). Deformation under an applied load in relation to the original length (L) of the rod is defined as the engineering strain (ϵ)

$$\epsilon = \frac{\delta}{L}$$

Most engineering structures are designed to undergo relatively small deformations, such that a linear proportionality between stress and strain is maintained. Hooke's Law defines this linear relation where a proportionality constant is obtained, known as the Modulus of Elasticity (E).

$$\sigma = E\epsilon$$

The linear relationship between stress and strain is only maintained if the original shape of the material is restored once the load is removed. This restoration is noted as elastic behavior and for ductile materials, a well-defined yield stress exists. These behaviors can be seen in the Figure 2 below.

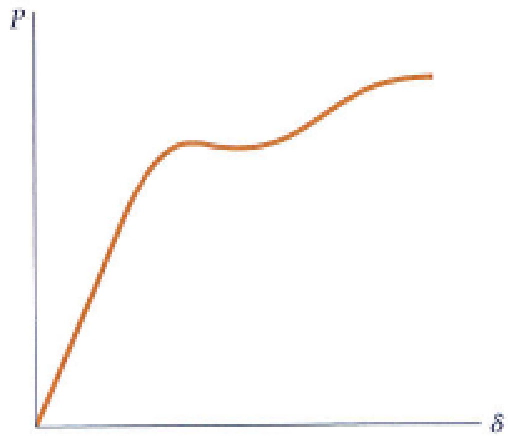

Figure 2: Stress vs Strain relationship.

Once the yield stress for a material is exceeded, the deformation is permanent and the linear relationship between stress and strain is lost. Permanent deformation for a material is known as plastic deformation and is commonly defined as the stress necessary to produce a plastic strain of 0.2%.

In ductile materials, the elongation to fracture is relatively long when compared to brittle materials. For ductile materials, the elongation can be up to 200 times larger than the deformation at yielding. A uniform elongation will continue until a decrease in diameter for a localized location of the material occurs. This occurrence is called necking and its onset defines the ultimate stress (σ_U) of the material. The stress needed to deform the material will decrease until fracture occurs. Necking and fracture can be seen in Figure 3.

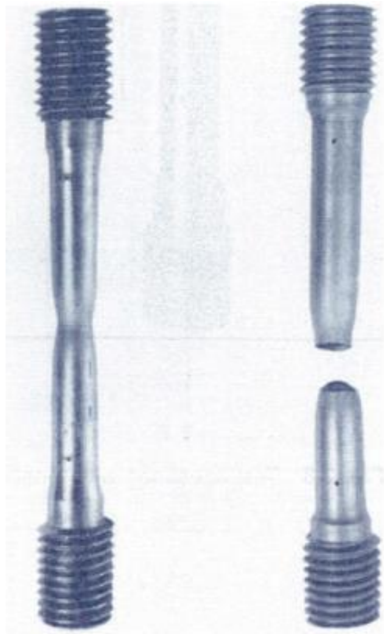

Figure 3: Necking and fracture for a ductile material.

For brittle materials, the change in the rate of elongation after the yield point does not occur. Fracture will occur at much lower stresses and necking will not occur, as seen in Figure 4. Thus, for brittle materials, the ultimate stress (σ_U) and stress at fracture (σ_B) are equivalent.

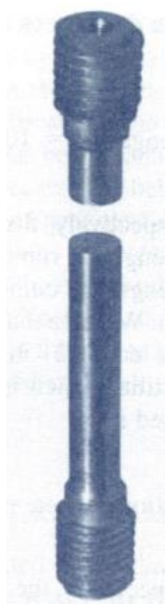

Figure 4: Fracture for a brittle material.

A measure of a materials ductility is its percent elongation based on the materials initial length (L_0) and final length (L_B).

$$\%\,Elongation = \frac{L_B - L_0}{L_0} \times 100$$

A percent reduction in area can also be used for ductility based on the materials initial cross-sectional area (A_0) and final cross-sectional area (A_B).

$$\%\ Reduction\ in\ Area = \frac{A_0 - A_B}{A_0} \times 100$$

1.2 Stress-Strain Diagram

During a tensile test on a material, a stress-strain diagram is commonly produced to highlight the important characteristics for the material. Figure 5 shows a common stress-strain curve representation for a ductile material. The elastic region of the material is easily identified as the linear portion of the curve at the onset of stress. The linear section ends to signify the yield stress location, with plastic deformation occurring. A maximum stress is realized and a decrease in stress with respect to deformation occurs to mark the beginning of necking. Fracture will occur soon after the ultimate stress is seen.

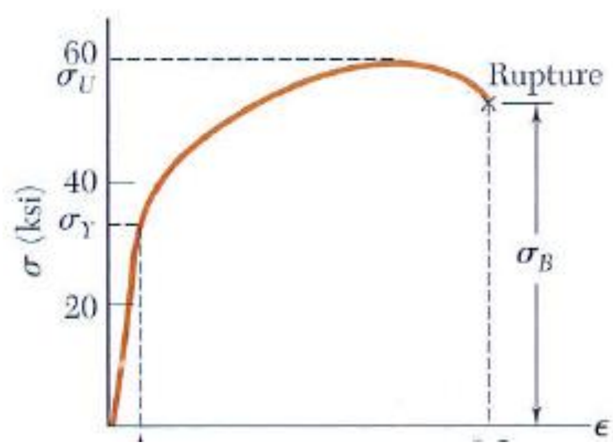

Figure 5: Stress-strain diagram for a ductile material.

During plastic deformation, a large amount of energy is consumed and is represented as the area under the curve on the stress-strain diagram. This energy corresponds to the amount needed to fracture the specimen and correlates to the materials toughness.

$$Toughness = \int_0^{\epsilon} \sigma\, d\epsilon$$

2 Experimental Procedure

2.1 Aluminum Sample

1. Select an Aluminum rod sample. Measure its dimensions and note them in your lab notebook.
2. Make sure the testing apparatus has been turned on and the operating software open,
3. Secure the sample in the testing unit based on the lab engineer's instruction.
4. In the operating software, set the experimental conditions (set the loading speed to 5 mm/min).
5. Secure the extensometer onto the testing sample (note the initial length based on the positon of the extensometer is **50 mm** and zero the force/deformation/displacement measurement.
6. Initiate the test and monitor the displayed stress-strain curve from the software.
7. Observe when the yield point occurs and the onset of plastic deformation.
8. Focus now on the sample to see observe the necking phenomena, which identifies ultimate strength. Feel free to have a lab classmate record this process with their phone camera.
9. When fracture occurs, note the final deformation value in your lab notebook.
10. Save the raw data recorded by the software for data analysis.
11. Remove the sample and measure final dimensions. Note signs of necking. Feel free to take pictures.
12. Repeat this entire process for 2 additional aluminum samples.

2.2 Cast Iron Sample

Repeat the previous steps for 3 cast iron samples with the loading speed set at 2 mm/min.

2.3 Analysis of Recorded Data

From the saved raw data, plot a stress-strain curve. From this data and your recorded data during experiment, you should be able to identify stress locations for yielding (0.02% offset method), ultimate stress and fracture. Approximate a linear relation for the elastic region and calculate a Young's Modulus. Calculate a ductility and toughness characteristic for both materials. Compare your calculated and observed values to known published values.

3 For the Report

In this experiment you tested two types of materials under axial tension to gain insight into their material characteristics.

In order to accurately analyze the data the following plots need to be made:

a) A complete stress-strain curve for each material.
b) A plot of the linear elastic region with offset curve intersection.
c) A curve fit of the elastic deformation region.

Along with the plots you will need to discuss the results. Include discussion points on elastic vs plastic deformation, ductile vs brittle material deformation and necking. Using a 95% confidence t-distribution, provide a probability interval for your calculated values.

The form of the report should be an extended memo. This will include a few paragraphs of theory and a description of the experiments, followed by results and discussion. Be sure to format your figures properly step the reader through your conclusions.