1.2.1 Experiment 1: Tension Test

Principle

Tension is created when a structural member is pulled from both sides. Under the effect of tension the member's length will increase and the cross sectional area will decrease. The elongation is a function of the load applied, the cross sectional area, the length, and the type of the material the member is made of.

Objective

The objective of this experiment is to understand tension loading and how the cross section area and the original length relate to elongation.

Background

Hooke's law states that the elongation is proportional to the force which describes the *elastic*, linear behavior of a material. The relationship is expressed as

$$\sigma = E\varepsilon.$$

The *normal stress* $\sigma = \frac{P}{A}$ is determined by dividing the magnitude P of the force by the cross sectional area A of the member perpendicular to direction of the applied force. The *strain* $\varepsilon = \frac{\Delta l}{l_o}$ is the ratio of change in length of loaded member to the original length l_o of unloaded piece. The proportionality constant E is called the *modulus of elasticity* of the material.

The elongation, $\Delta l = l - l_o$, of a structural member with uniform cross section subjected to axial loading can be determined by

$$\Delta l = \frac{Pl_o}{AE}.$$

For example, if a steel rod ($E = 30 \times 10^6$ psi) , ¼-in uniform diameter and 12-in long, is axially loaded with a force 6 lbf. The above formula predicts that the steel rod would stretch a mere 0.00005 in (or 0.00124 mm in the SI metric system). The elongation is an infinitesimal quantity, one-twenty thousandth of an inch!

Apparatus

- Test specimens of rubber.
- Test weights and weight holder
- Rulers
- Support stand and clamps

Procedure

Case 1 - One 12-inch long rubber rod, ¼ in diameter:

- Hang the rubber rod from the top of the stand using the clamps.
- Hang a weight holder through the hole drilled at the bottom of the rod.
- Measure the initial length l_o between the holes at the bottom and the top of the rod.

- Apply a 2 lb weight and measure the elongated length $l = l_o + \Delta l$.
- Increase the weights in 1 lb increments up to 6 lb, and each time measure the elongated length.

Case 2 - One 18-inch long rubber rod, ¼ in diameter:

- Repeat the steps described above using a 1.5 ft long rubber rod.

Case 3 - One 12-inch long rubber rod, $\frac{5}{8}$ in diameter:

- Repeat steps of Case 1 described above using the bigger rubber rod.

This experiment is designed to illustrate the relationship between tension load and elongation. The experiment is done using rubber rods in order to exaggerate the change in length. However, it must be understood that in real structural elements the change in length is normally smaller than that observed in this experiment.

Presentation of Results

Determine the area $A = \pi D^2/4$ in² of the test specimens in each case. Record the data in a table with the first column load $P = mg/g_c$ lbf, the second column measured elongation Δl in, third column stress $\sigma = F/A$ psi, the fourth column strain $\varepsilon = \Delta l/l_o$, and fifth column theoretical elongation $\Delta l = Pl_o/AE$ in. Obtain E from a materials handbook. (Take $g = 32.174$ ft/s² and $g_c \equiv 32.174$ lbm ft / lbf s²).

Plot the three cases described above on the same graph showing the relationship between the applied loads (on the vertical axis) and the measured elongations (on the horizontal axis). Choose a suitable scale for the coordinates.

Also, plot the relationship between the applied stress (force per unit area) on the vertical axis and the strain (elongation per unit length) on the horizontal on another graph sheet for the three cases.

Analysis of Results

Study how the applied load and elongation relate to each other. Study and discuss the similarities and the differences between the graphs plotted. How would the graph change if a stronger material such as steel is used instead of rubber? Does the slope of each graph in the initial stages of loading relate the applied loads to the measured elongations linearly? (The slope of the initial linear part of the graph obtained by plotting the applied stress versus the applied strain is called the modulus of elasticity and is a function of the type of material and the strength of material used). Do the slopes converge to same value for the three cases? How close to each other is the value of the slope and/or to the standard value taken from the materials handbook?