LABORATORY # 2: ELASTIC PROPERTIES OF RUBBER

OBJECTIVE:

In this laboratory you will be determining the Elastic Modulus and Poisson's Ratio of rubber.

Apart from the illustration this will provide you with of this property of materials this laboratory provides you with the opportunity to practice describing equipment and experimental procedure, with appropriate illustrations of the equipment used, along with an appropriate text explaining the use of the equipment.

THEORY:

Engineering stress σ is defined by the following equation

$$\sigma = \frac{F}{A_o}$$

where F is the instantaneous load applied perpendicular to a particular material sample (specimen) cross-section, in units of newtons (N) or pounds force (lb_f), and A_o is the original cross-sectional area of the sample (specimen) before any load is applied (m^2 or in^2). The units (International System of Units (SI) and traditional units of British or U.S.A) of engineering stress are megapascals, MPa, (where 1 MPa = 10^6 N/m^2) and pounds force per square inch, psi.

Engineering strain ε is defined by the following equation

$$\varepsilon = \frac{l_f - l_o}{l_o}$$

where l_o is the original sample (specimen) length before any load is applied, and l_i is the instantaneous length. Sometimes the quantity l_i-l_o is denoted Δl, and is the change in length at some instant, referenced to the original length. Engineering strain can be reported without units or typically with units as meters per meter or inches per inch. Strain may also be expressed as a percentage by multiplying by 100.

The slope of the stress-strain curve in the elastic region is the modulus of elasticity, E, also known as Young's modulus. The linearity of the stress-strain plot in the elastic region is a graphical statement of Hooke's Law:

$$\sigma = E\varepsilon$$

The modulus, E, is a highly practical value since it represents the stiffness of the material or its resistance to elastic deformation. The units of modulus, E, are usually in gigapascals, GPa, (where 1 GPa = 10^9 N/m^2) and pounds force per square inch, psi.

When a materials is elastically deformed in tension there is an extension associated with the tension as well as a contraction perpendicular to the extension. From these extensions and contractions, the axial strains can be measured in the x, y, and z directions. From these values the ratio of lateral and axial strains are defined as Poisson's ratio, ν, as given in the following equation:

$$\nu = \frac{-\varepsilon_x}{\varepsilon_z} = \frac{-\varepsilon_y}{\varepsilon_z}$$

In this equation for Poisson's ratio, ν, a negative sign is included in the expression so that ν will always be positive, since the lateral and axial strains will always be of opposite sign. Poisson's ratio is reported without units and values range from 0.25 to 0.35 for many metal alloys.

EXPERIMENTAL:

In this laboratory an O-ring will be extended on a pulley by hanging a T-bar and weights. The axial extension of the O-ring will be measured for both the addition and subtraction of the weights by using a rule, micrometer, vernier caliper, and traveling microscope.

1. Set-up the stand with a clamp holding a pulley supporting an O-ring.
2. Identify the diameter and length of the O-ring with weight hook attached*.
3. Measure the original distance between measuring clips.
4. Add weight to the weight hook and measure again.
5. Repeat with two weights and then with a total of three weights on the weight hook recording the diameter, length, and total weight in a table as each weight is added.
6. Repeat these measurements while removing the weights from three to two, two to one and one to just the weight hook.

*When using the traveling microscope, take the value of one side of the O-ring, then move the microscope to take the reading on the other side of the O-ring. Subtract the two measurements to obtain the diameter of the O-ring.

A table of values can be created to record the Weight Added (g), Total Weight or mass M (g) , Distance Between Clips L (mm), Diameter of O-ring D (mm).

The following calculations can be made from the data and placed in a table:
Lateral Strain (ε_x) $\varepsilon_x = \Delta D/D_o$
Axial Strain (ε_z) $\varepsilon_z = \Delta L/L_o$
Area (A) $A = \pi r^2$
Force (F) $F = ma$
Stress (σ) $\sigma = F/2A$
These values will be recorded along with the % uncertainty of measurements. The combined values of uncertainy should be added to the total uncertains of each calculation when more than one variable is involved.

A graph can be created for the stress versus strain values when adding weights and removing weights by using a personal computer in the laboratory. The slope of the graph can then be determined, in terms of its "best fit" straight line, to calculate the Elastic Modulus, E, (Young's Modulus). The uncertainties in this measurement of E will come from the combined uncertainties of calculating stress + uncertainties of calculating strain.

The Poisson's ratio, ν, will also be calculated from the strain data. The uncertainties in the measurement of ν will come from the combined uncertainties in the measurements of lateral and axial strain that come from the combined uncertainties in the measurements of the diameter and length of the O-ring.

Add a discussion of the results and uncertainties.

A conclusion that reports the main findings of the elastic (Young's) modulus and Poisson's ratio of a rubber O-ring and the uncertainty will finish the laboratory report.

References:

1. W.D. Callister, Materials Science and Engineering: An Introduction, 6th Edition, John Wiley & Sons, 2003. (Chapter 6: Mechanical Properties of Metals)
2. J.F. Shakelford, Introduction to Materials Science for Engineers, 6th Edition, Pearson Education, Prentice Hall, 2004. (Chapter 6: Mechanical Behavior)