LAGUARDIA COMMUNITY COLLEGE

MAE101-XXXX
ENGINEERING LABORATORY I

EXPERIMENT 2: Tension Test

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Abstract

In this experiment, we observed the elongation phenomena in rubber rods. Then, we calculated their theoretical elongation values and compared these results to observed results. By showing similar real vs. theoretical elongations, we proved Hooke's law.

Introduction

It is imperative to be able to determine elongation values for any material that is designed to be under a tension load. When the consequences could be as severe as the collapse of a suspension bridge resulting in fatalities, we must be able to prove that the material used will never reach its yield strength. As Heller (2002) explains, metals inherently have a linear stress vs. strain slope during elastic deformation. However, once the metal's yield strength is reached, plastic deformation will occur and elongation will grow disproportionately to stress. This true for most materials, but not all. Raftenberg, Scheidler, and Moy (2004) prove this with their stress strain analysis of a multi-ply Kevlar vest where modulus of elasticity was a non-linear function.

In this experiment we will exhibit the concept of tension by applying an incrementally larger load to three rubber rods of varying lengths and diameters while taking measurements of the rod's elongation between each increment. We will then analyze the data obtained and determine what relationship exists between applied load and elongation. Finally, we will discuss relationships between the three cases and hypothesize what results we would expect from testing steel instead of rubber.

Objective

The objective of the experiment is to understand tension loading and how the cross sectional area and length of the rod relate to elongation. Hooke's law states that elongation is proportional to the tension force applied. This is expressed as:

$$\Delta l = \frac{P l_0}{AE}$$

Where $\Delta l = l - l_0$, P is the applied force, A is the cross sectional area of the rod, and E is the modulus of elasticity.

Next we will prove that a linear relationship exists between stress (σ) and strain (ε). This relations ship can be seen in the following formula:

$$\sigma = E\varepsilon$$

Also, we will prove that for a given material, we can change the structures dimensions and still arrive at the same modulus of elasticity by plotting stress vs. strain.

Experimental Procedures

Construct a stable structure from a tripod and metal rod. Then attach a multi-clamp near the top of the metal rod.

Case 1 - Hang the rubber rod with l_0 = 11.687 in and 0.2735 in diameter (by a hook taped to the side at the top of the rod) to the multi-clamp. Attach the weight holder eyebolt to the other hook (taped to the side of the rod at the bottom of the rod). Measure the initial length l_0 between where the hooks are attached to the rubber rod. Measure the uniform diameter of the rod. Now, 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 – Repeat the steps described above using a rubber rod 17.125 in long and 0.2735 in diameter.

Case 3 – Repeat the steps described above using a rubber rod 11.3125 in long and diameter of 0.6370 in.

Results

Case 1

$l_0 = 11.687$ in, $D = 0.2735$ in

$$A = \frac{\pi D^2}{4} = \frac{\pi \bullet (0.2735)^2}{4} = 0.05875 \text{ in}^2$$

Table 1

P (lbf)	$\Delta l = l - l_o$ (in)	$\sigma = F/A$ (psi)	$\varepsilon = \Delta l / l_o$	$\Delta l = P l_o / AE$ (in)
2	0.875	34.04255319	0.074866	1.584977173
3	1.8125	51.06382979	0.15508	2.377465759
4	2.75	68.08510638	0.235294	3.169954346
5	4.0625	85.10638298	0.347594	3.962442932
6	5.5625	102.1276596	0.475936	4.754931519

Case 2

$l_0 = 17.125$ in, $D = 0.2650$ in

$$A = \frac{\pi D^2}{4} = \frac{\pi \bullet (0.2650)^2}{4} = 0.055155 \text{ in}^2$$

Table 2

P (lbf)	$\Delta l = l - l_o$ (in)	$\sigma = F/A$ (psi)	$\varepsilon = \Delta l / l_o$	$\Delta l = P l_o / AE$ (in)
2	1.875	36.26144502	0.109489	2.514077919
3	3.3125	54.39216753	0.193431	3.771116878
4	4.9375	72.52289004	0.288321	5.028155838
5	6.8125	90.65361255	0.39781	6.285194797
6	9	108.7843351	0.525547	7.542233756

Case 3

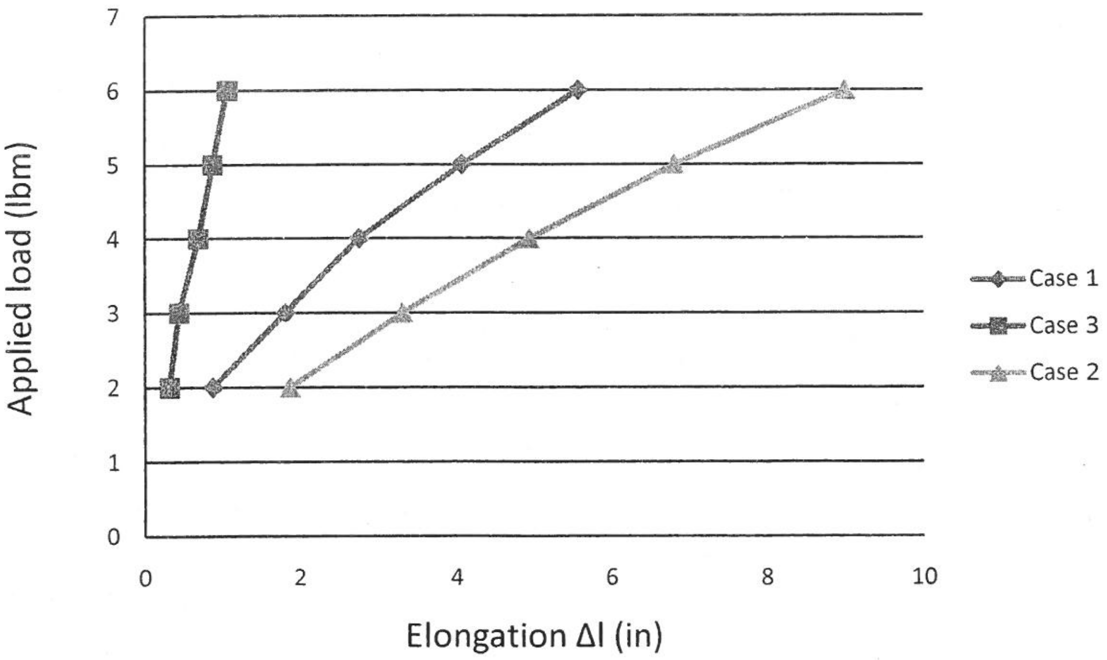
$l_0 = 11.3125$ in, $D = 0.6370$ in

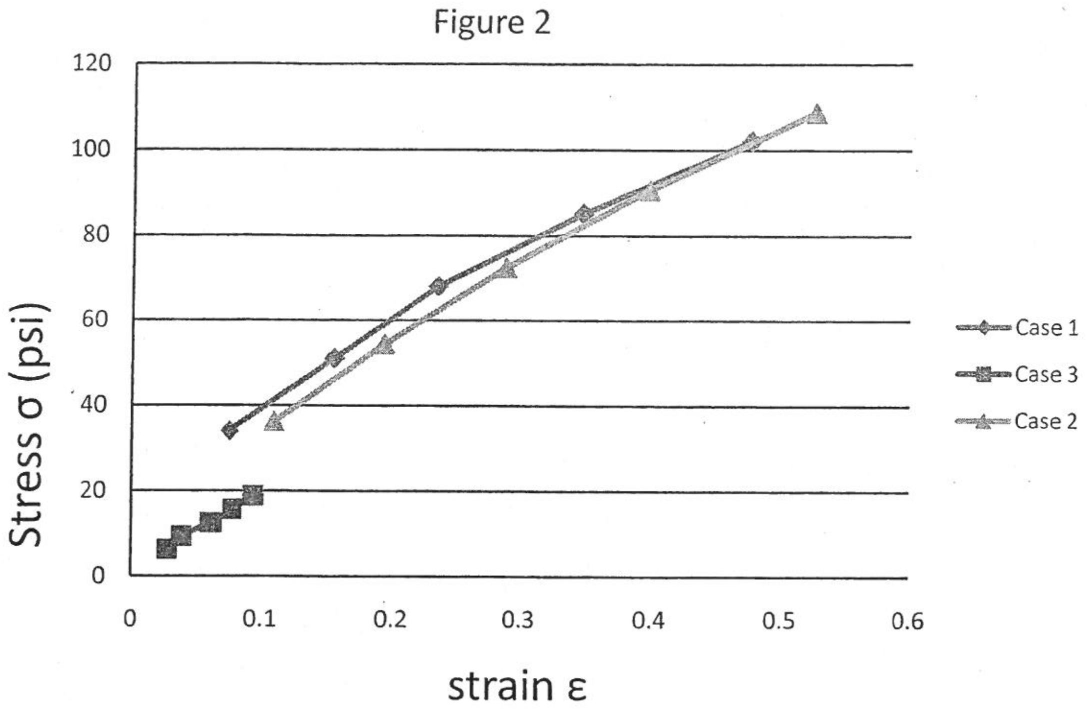
$$A = \frac{\pi D^2}{4} = \frac{\pi \bullet (0.6370)^2}{4} = 0.31869 \text{ in}^2$$

Table 3

P (lbf)	$\Delta l = l - l_o$ (in)	$\sigma = F/A$ (psi)	$\varepsilon = \Delta l / l_o$	$\Delta l = P l_o / AE$ (in)
2	0.3125	6.27569111	0.027624	0.287424112
3	0.4375	9.413536666	0.038674	0.431136168
4	0.6875	12.55138222	0.060773	0.574848224
5	0.875	15.68922778	0.077348	0.71856028
6	1.0625	18.82707333	0.093923	0.862272336

Figure 1





Discussions

Figure 1 shows how changing the dimensions of a given material will effect elongation. For example, case 1 shared the same cross sectional area with case 2, but case 2 was 50% longer. As Hooke's law states: initial length is proportional to elongation. Thus, we would expect case 2 to elongate a greater amount for the same increase in force, compared to case 1. Figure 1 proves this. The same logic applies to the comparison of case 1 and case 3. Because case 3 had a nearly equal length, but larger cross sectional area, and cross sectional area is inversely proportional to elongation, we would expect case 3 to elongate less than case 1 for the same force applied. Figure 1 also supports this.

As illustrated in figure 2, despite the different dimensions of the rods, nearly the same slope (*E*) was observed for the initial portion of each function. This proves that modulus of elasticity for any given material is constant despite changes in dimension of the material's application.

The higher the strength of the material we use, the steeper we would expect the stress-strain slope to be. For example, if we were to graph stress vs. strain of steel we would see an extremely steep linear function compared to these rubber rods since steel's modulus of elasticity is magnitudes larger than rubber.

Conclusions

We observed elongation in relation to an incrementally increasing force, and our results determined that there is a linear relationship between stress and stain for forces less than the material's yield strength. We conducted hand calculations to determine what the theoretical elongation should have been, using Hooke's law. There was some error in the results, but this is due to inaccuracies in measurements. These errors could be minimized by constructing rubber rods with a rope line taped to opposite sides of the rubber rod so that the rod does not bend out of the Y axis by an adjacently attached hook. Despite these small differences, Hooke's law was proved.

References

Benenson, Ganatos, Ghosn. Activities and Assignments for ENGR 10100: Engineering Design Freshman Manual. Third Edition. 2006.

Heller, Robert A. "Mechanics of Structures" Encyclopedia of Physical Science and Technology. 3rd Edition. Vol 9. 2002.

Raftenberg, Martin; Scheidler, Michael; Moy, Paul. Transverse Compression Response of a Multi-Ply Kevlar Vest. ARL-TR-3343. September 2004

Lab Report Format

1. **Title Page**
   This page should include the department and number of the class, the date, and the names of the students who performed the lab and wrote the report.

2. **Abstract**
   The abstract is a very concise summary of the experiment and the results obtained. It is usually a single paragraph (just a few sentences) long, though in some cases, it may be somewhat longer.

3. **Introduction**
   The introduction serves to set up the reader for the rest of the report. It includes background information, as well as a description of how this work fits into the broader/wider contexts of the class, field, discipline, etc. It sometimes includes a description of the principles that underlie the experiment, but the details of the work usually fit better into later sections.

4. **Theory**
   This section is used to present and/or derive any equations that will be needed to understand the experiment or perform the data analysis.

5. **Procedure**
   In this section, the details of the way the experiment was performed, how the equipment was configured, the way the data was collected, etc., are described. You will likely refer to the handout quite a bit in this section.

6. **Results**
   Include both results, as well as sample calculations when appropriate.

   - Make sure results are clearly labeled and set off from the text somehow (eg, in a table or graph), and not simply imbedded in the text.
   - Think carefully about whether the information is better presented in a table, a graph, or both. (It is not usually necessary to present the same information in both a graph and a table, though it can occasionally be helpful.)
   - Show experimental and theoretical results side by side for easy comparison, e.g. in the same table or graph. In tables, include the percentage deviations of the experimental results from the theoretical predictions. This is important!

7. **Discussion**
   This section is used to demonstrate the significance of the results, and to explain why they are or are not consistent with those that would be expected from theory and analysis.

   - Discuss the significance, or meaning, of the results.
   - Discuss discrepancies between theoretical and experimental results, and their likely causes.
   - Discuss any difficulties encountered in performing the laboratory.