Lab 7 – Strain gage Application and Testing

Section 5, Group 5
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10/27/2023

Introduction

Strain gages are a widely used technology for estimating loads and strains on a plethora of various materials, including wide usage in the aerospace industries to determine the efficacy of aircraft structures. During the course of this two-week lab, our group was given the opportunity to experiment firsthand with strain gages in a tensile and bending test on an aluminum specimen to analyze real world results of materials tests. Our first step was to install a strain gage to the sample and then perform testing.

Objective

Our objective is to gain hands on knowledge of strain gage testing, procedures, and applications.

Hypothesis

We surmise that our testing data will yield more accurate results than theoretical approximations. If measured correctly, after correcting for errors, the data we collect should match very closely with exact theoretical results. The graph should accurately report a linear elastic region with a jump at the origin.

Variables

Variables include load F, gage factor, gage resistance, and elongation. Also, to be considered material properties of the specimen. Length, width, and thickness of specimen.

Work Assignments

For the in-person part of this lab, the assignments were split fairly. Joseph cleaned and sanded the material for the strain gage, while Lucas placed the gage on the material using the tape. Isaac and Ethan did these parts for installing the second strain gage so everyone could contribute. All four of us each did one wire for the soldering, and then Lucas put the markings on the tape for the video extensometer.

For the report, Ethan did the materials, apparatus, and procedures section, and Joseph did the coding and obtained the graphs. Isaac did the introduction, hypothesis, objective, and variable sections. Lucas wrote the conclusion. For the analysis section, we all contributed in some way to it.

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Materials, Apparatus, Procedures

Figure 1. Tools and material (Lab 7 strain gage application and testing (starts oct 12).pdf)

The experimental setup for this laboratory exercise involved the utilization of an aluminum specimen, which served as the primary test material. This aluminum specimen, measuring 8 inches in length and 2 inches in width, was initially subjected to careful preparation. Any protective plastic film was removed, and the specimen's center was distinctly marked on both surfaces, with particular attention to marking the centerline on the longer side. This process was vital for subsequent accurate strain gage application.

The specimen underwent a detailed surface preparation to ensure adequate bonding between the strain gages and the specimen's surface. This involved a series of steps, including degreasing, sanding, and cleaning. Specifically, the surface was degreased using a degreaser, sanded with sandpaper in a circular motion, and cleaned with cotton swabs and acetone. The gage installation areas were lightly sanded with 200 to 400-grit sandpaper, ensuring that an area approximately twice the length of the strain gage on both dimensions was sanded. A final deep cleaning was done using swabs.

Following the surface preparation, two strain gages were installed on both sides of the aluminum specimen. Each strain gage was placed on a glass slide with the side containing lead wires and terminals facing upwards. To securely attach the strain gage to the specimen, a tape strip was folded with one end to form a non-sticky patch, while another tape strip was folded with non-sticky tabs on both ends for easier handling and peeling. The latter strip served as the carrier tape.

The "carrier" tape strip was positioned directly above the strain gage on the glass slide to attach the strain gage to the aluminum specimen. Careful attention was paid to align the tape with the marked center location on the sample. The tape was lightly pressed down onto the specimen's surface, and any unsatisfactory positioning was corrected by peeling off the tape and reattempting.

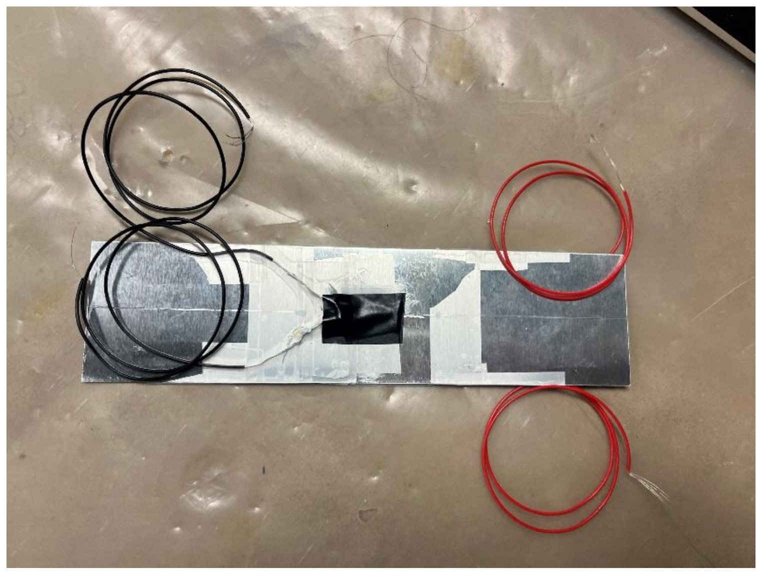

Figure 2. Completed strain gage installation

Once the positioning was satisfactory, the "carrier" tape was slowly peeled off the specimen, allowing the strain gage to adhere to the surface. A tiny drop of glue was applied from the 496 Bonder to the specimen's surface where the gage was located, and the gage was carefully pressed back onto the specimen. The tape was peeled off after the adhesion process to reveal the installed strain gage. The gage's lead wires were insulated by taping the specimen's surface area below the lead wires to prevent contact with the metal surface. Additionally, a strip of non-sticky tape was used to protect the gage by covering it, allowing it to expand freely while shielding it from potential damage.

The installation process was repeated for the second strain gage on the backside of the specimen. A layer of paper towels was placed underneath the specimen during the second installation to prevent any damage to the previously installed gage. This comprehensive strain gage installation process ensured that strain could be accurately measured on both sides of the aluminum specimen. See Figure 2 for the completed product.

Bending Test:

The first part of the experiment involved a bending test. In this test, the strain gages installed on the aluminum specimen were connected to a P3 strain reader (Figure 3). This reader was configured as a half-bridge I gage-adjacent setup, with one gage measuring the strain on the top of the specimen and the other measuring the bottom side. The specimen was placed on a wooden stand, ensuring the gage was positioned in the middle of the span. Small flat spacers were placed around the gage to distribute the load more evenly. The P3 strain reader was balanced to zero, and the vertical deflection of the specimen was measured using a caliper, simultaneously recording the strain reading from the P3 strain reader. This process was repeated multiple times to obtain accurate data for the bending test.

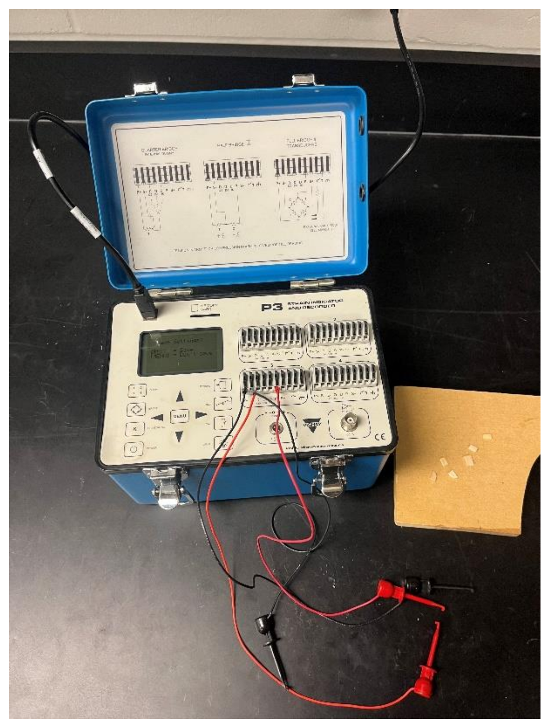

Figure 3. P3 strain reader

Compliance Test (for calibration):

Before proceeding with the tensile test, a compliance test was conducted to calibrate the Instron test system. For this test, a thicker steel plate, acting as a rigid body, was used to minimize system errors in elongation measurements. The calibration process aimed to ensure accurate measurements in subsequent tests. This test is shown in Figure 4.

Figure 4. Compliance test

Tensile Test:

The primary focus of the experiment was the tensile test (shown in Figure 5). Three sets of data were collected simultaneously during the test: load vs elongation data from the Instron dual-column test system, strain changes at the gage measured by the P3 strain reader, and distance changes between fiducial marks on the specimen recorded by a video extensometer.

The specimen's wires were connected to the lead wires of the P3 strain reader, setting up a half bridge II configuration. The video extensometer measured the distance change between two fiducial marks painted on the specimen. The Instron test system, equipped with Bluehill Universal software, was used to apply tension to the specimen. The specimen was secured in the side-action grips on the Instron machine, ensuring proper alignment and minimal wiggle room.

To convert elongation into strain, the gage length between the grips was measured using a caliber. The Instron machine was set up for data collection, and the video extensometer was powered on. The P3-D4 application software controlled the P3 strain reader through a USB connection, while the Bluehill Universal software managed the Instron test system.

The experiment was carried out by recording load vs. elongation data, strain measurements from the P3 strain reader, and video extensometer data. The data collection process was conducted multiple times to ensure accuracy. Upon reaching a load of 300 lbs, the test automatically stopped, and data was collected. The data included load, elongation, and strain measurements, and the experiment was completed.

The compliance test and tensile test determined the aluminum specimen's mechanical properties, including its Young's modulus. These tests were crucial for understanding the material's behavior under different loading conditions and assessing its suitability for aerospace applications.

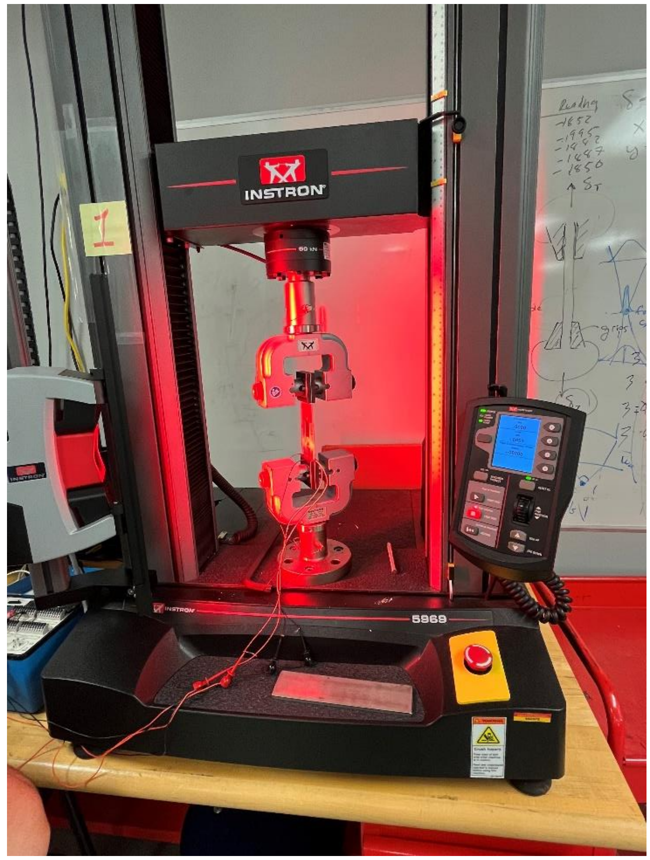

Figure 5. Tensile test

Data

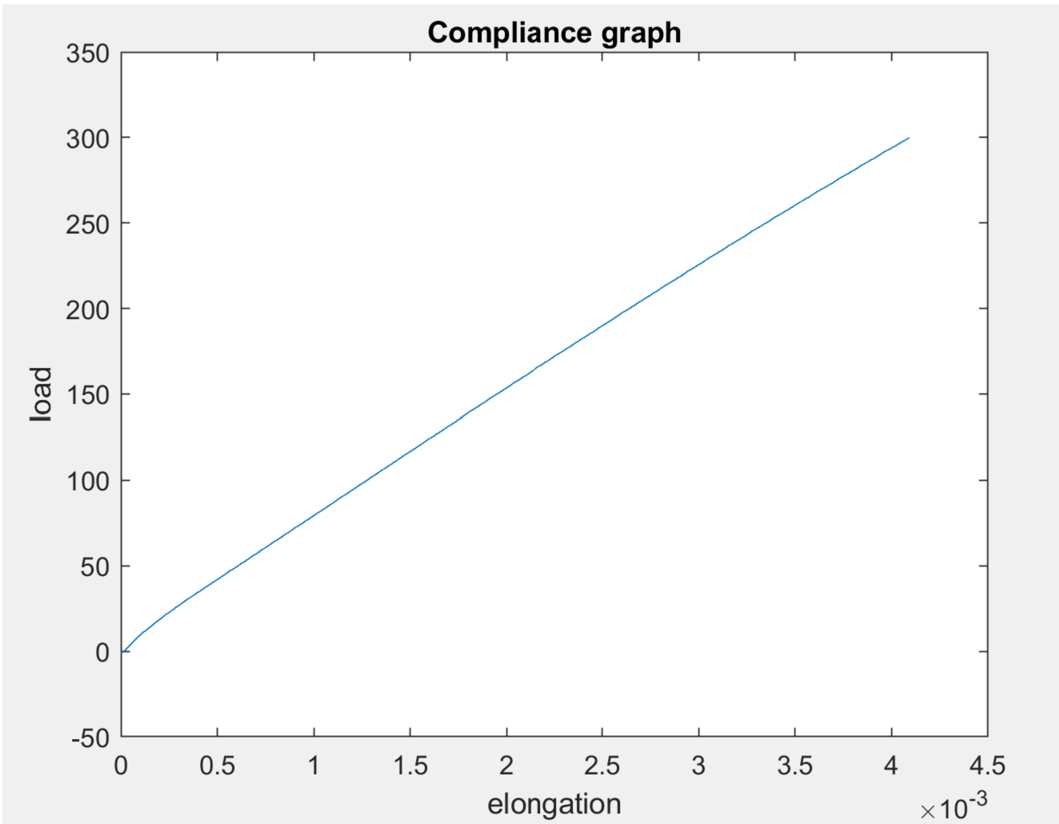

Figure 6: compliance graph of load(lbs) vs. elongation(inches)

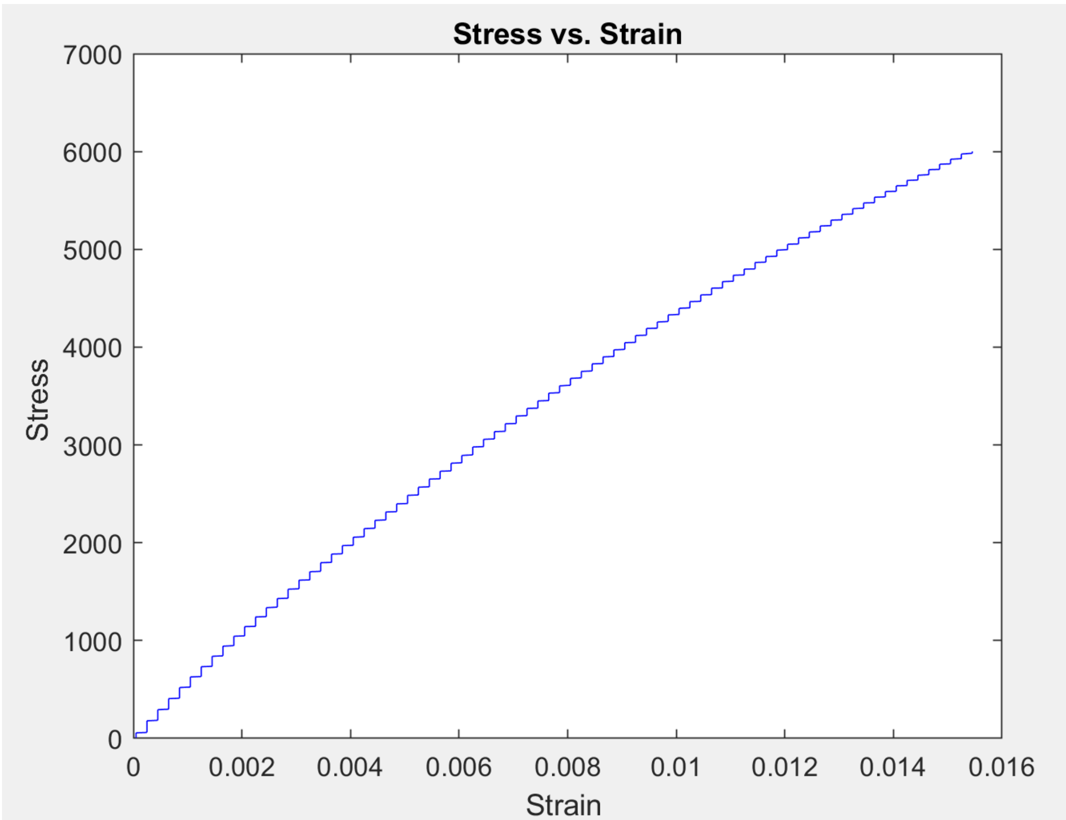

Figure 7: Stress(lbs) vs. Strain curve after correction

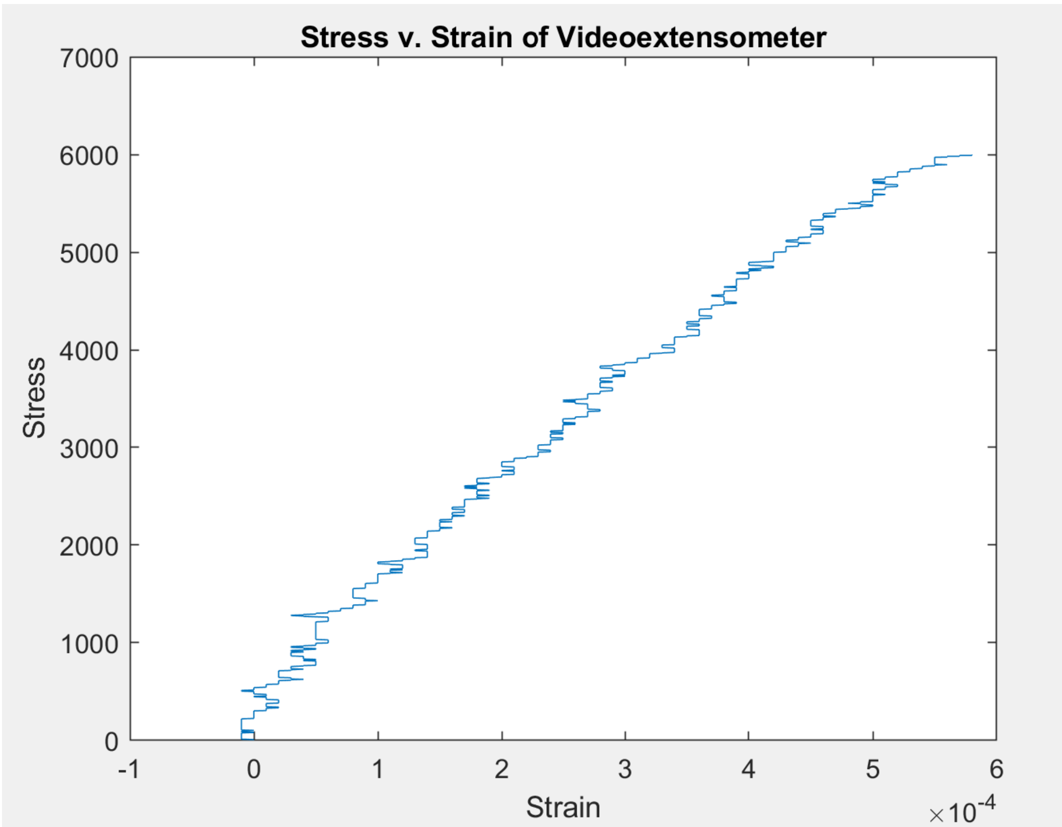

Figure 8: Stress(lbs) vs Strain curve using video extensometer

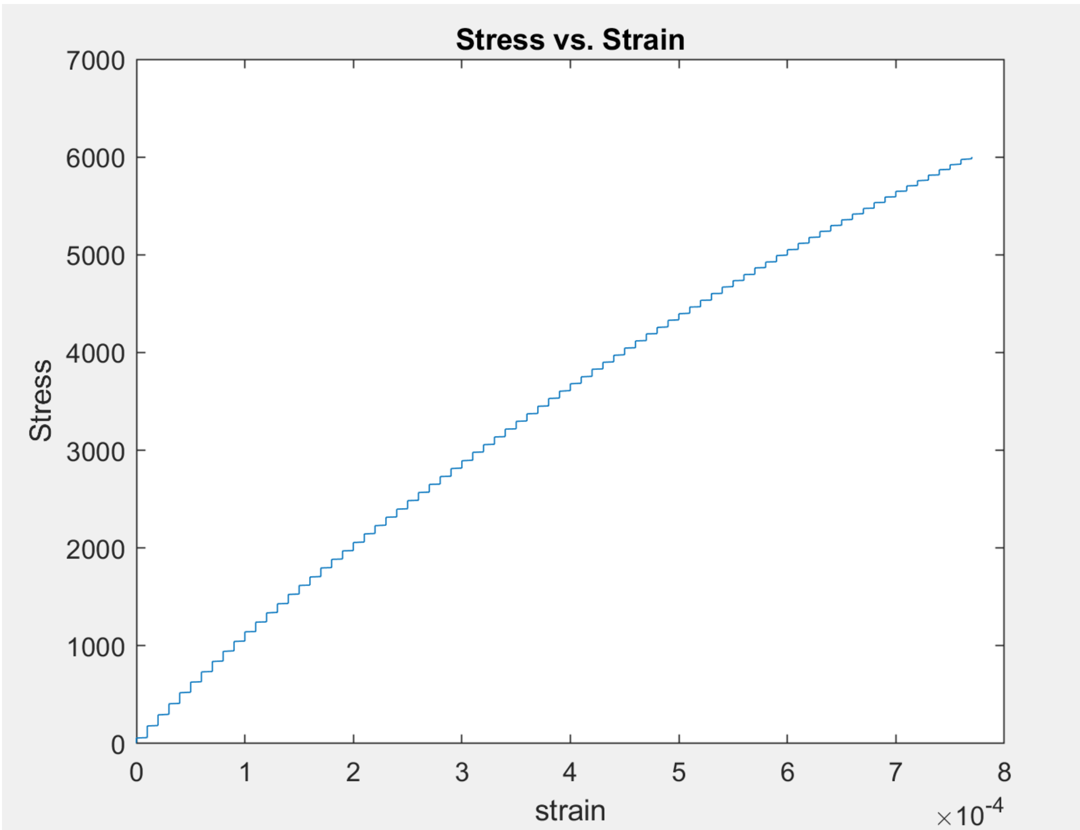

Figure 9: Stress vs. strain gage

Analysis

i. When attempting to put the specimen under tensile stress by hand, no change in the strain gage reporting was detected. The likely cause is that the device used to read the strain gage in the bending test was not calibrated for strains in transverse dimensions, as it will be significantly less sensitive due to the more significant physical change in the strain gage. To verify this, we can use the Wheatstone bridge equation for a half bridge given by:

$\frac{V}{E} = \frac{R+\Delta R}{2(R+\Delta R)} - \frac{R}{R+R}$, as both terms simplify to $\frac{1}{2} - \frac{1}{2} = 0$ this indicates that the specific setup is only calibrated for inverse changes across the strain gage due to bending stress.

ii. In similar fashion to (i), the fact that no change was detected was certainly due to the calibration being set for only positive (or tensile) increases in resistance across the gages as they were pulled. For the half bridge, we can show this:

$$\frac{R+\Delta R}{2R+\Delta R} - \frac{R}{2R-\Delta R} = \frac{V}{E} = \frac{2R^2-\Delta R^2+2R\Delta R-R\Delta R-2R^2-R\Delta R}{(2R+\Delta R)(2R-\Delta R)} = \frac{-\Delta R^2}{(2R+\Delta R)(2R-\Delta R)}$$

Expanding the second denominator term via binomial theorem, starting at n = -1, as the series expands, the R terms will increase in power in the numerator as the ΔR term grows smaller proportionally, showing that the R term is significantly more weighted than the change in R, hence when bending the change is essentially negligible.

iii. Given:

$$y_{max} = \frac{PL^3}{48EI}, \sigma = E\epsilon, \sigma = \frac{PLy}{2I}$$

We can rearrange these equations by setting the second to equal to each other and solving for P.

$P = \frac{2EIL\epsilon}{Ly}$, plugging this into our equation for max deflection, we find $\epsilon = \frac{24y_{max}y}{L^2}$

Evaluating for a load of .5 kg * g, max deflection of 2.8 mm yields a strain of <u>5.3178e-5 = 53.18</u>$\mu\epsilon$. This is similar to the strain of ~50$\mu\epsilon$ reported by the test.

iv-x. The Young's modulus for the first graph, when only using elongation, was 3,911 ksi. The Young's modulus for the second graph, which used the strain from the video extensometer, was 10,420 ksi. The data from the video extensometer was not as noisy as we expected it to be, and because of this, no data smoothing was applied to it. We don't believe it negatively affected our data because we got a Young's modulus close to the expected value. The Young's modulus for the third graph was based on the strain gage, which was 8,220 ksi.

After conducting and processing these three tests, the worst way to measure the strain of a material is to measure its elongation and then convert that to strain. This could be seen from the elastic modulus which was not accurate to the known elastic modulus. The best process to calculate strain is a video extensometer, as the elastic modulus found from the data it gave was extremely close to what the known elastic modulus is. The negative that comes with the video extensometer is that it is expensive, takes additional time to set up, and the markings must be large enough and in a proper area for the device to read properly. The strain gages also gave fairly accurate readings, but for how inconvenient it was to assemble, solder, and then use them correctly was sub-optimal compared to the ease of use of the video extensometer.

Conclusion

During the first lab day, our group gained valuable experience and knowledge about setting up strain gages. It became clear how handling the installation with calm and precision can bring better results during the tests. Strain gages are devices with a delicate installation process that get valuable information about the structures and materials tested.

The tests we conducted were extensive and required a good deal of time-consuming effort to set up. Regardless of the effectiveness of each type of test and the setup required, we gained insights into conducting accurate and reliable tensile and bending tests. Comparing the results obtained from the different methods, the video extensometer data came out to be the closest to the theoretical analysis. On the other hand, the strain gages collected fairly accurate data. It is a considerably cheaper device compared to the video extensometer but much harder to assemble.

References

Chiou, Thomas. "Lab 7 strain gage application and testing (starts oct 12).pdf" Iowa State University. 2023