ME 4005 Lab Report 2 – Beam Strain Gauge

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Introduction

Lab two covers the interpretation of signals from a quarter bridge model connected to a MSP432 Data Acquisition System (DAQ) to determine experimental values for strain and deflection. This requires understanding of how to read voltage signals and how a simply supported beam performs. The behavior of a theoretical beam in the conditions that will be explored experimentally in the lab is modeled through the below equations for tip deflection and bending stress, also of use is the below re-arranged equation for Young's Modulus.

$$\delta = \frac{FL_2^3}{3EI} \tag{1}$$

$$\sigma = \frac{My}{I} \tag{2}$$

$$\varepsilon = \frac{\sigma}{E} \tag{3}$$

The variables for the equations seen above are defined in Table 1 below.

Table 1: Defining Variables for Equations 1 - 3

Variable (s)	Value Represented
E	Modulus of Elasticity (Young's Modulus)
δ	Tip Deflection
y	½ Height of Beam
F	Applied Force
L_2	Length of Beam (Measured from wall to tip)
I	Area Moment of Inertia of Beam

The main lab objectives were to determine strain on a cantilever beam through utilizing a strain gauge and Wheatstone bridge (WSB); to determine WSB output voltage for five different loads and base (un-loaded) state; to utilize experimental data to calculate an experimental Modulus of Elasticity (MoE) and estimate tip deflection; to compare experimental and theoretical MoE and tip deflection data. [1].

Methods

In conducting lab two the student is tasked to collect data on the WSB via use of the provided MSP432 DAQ, therefore the first step is to open the Graphical User Interface for the MSP432 via MATLAB. The circuit shown below in Figure 1 is then constructed by the student.

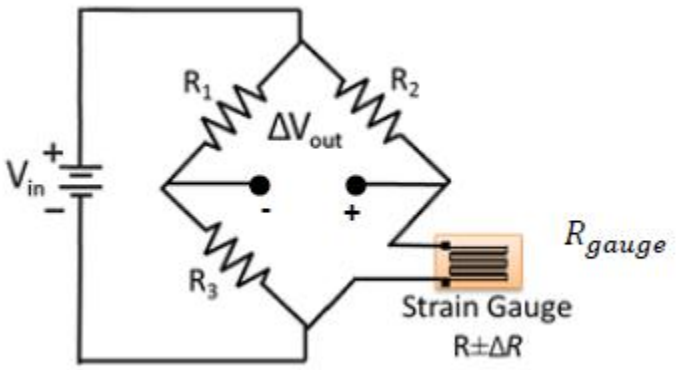


Figure 1: Quarter Bridge Circuit

Before the student moves on to part 2 of the lab the strain gauge must first be tested to see if it is still operational. The process to do this is to record the output voltage then manually move the tip of the beam such that the gauge is slowly put under more tension while observing the output voltage. The output voltage for a properly working strain gauge will increase during tensioning. For part 2 of the lab the student places the quarter bridge on a flat surface so that none of the bridge is suspended without support. This serves to calculate the offset voltage and find the output voltage when resistors are added to the strain gauge in series and parallel. The experiment is set up according to Figure 2 below such length 2 measures exactly 9 inches [1].

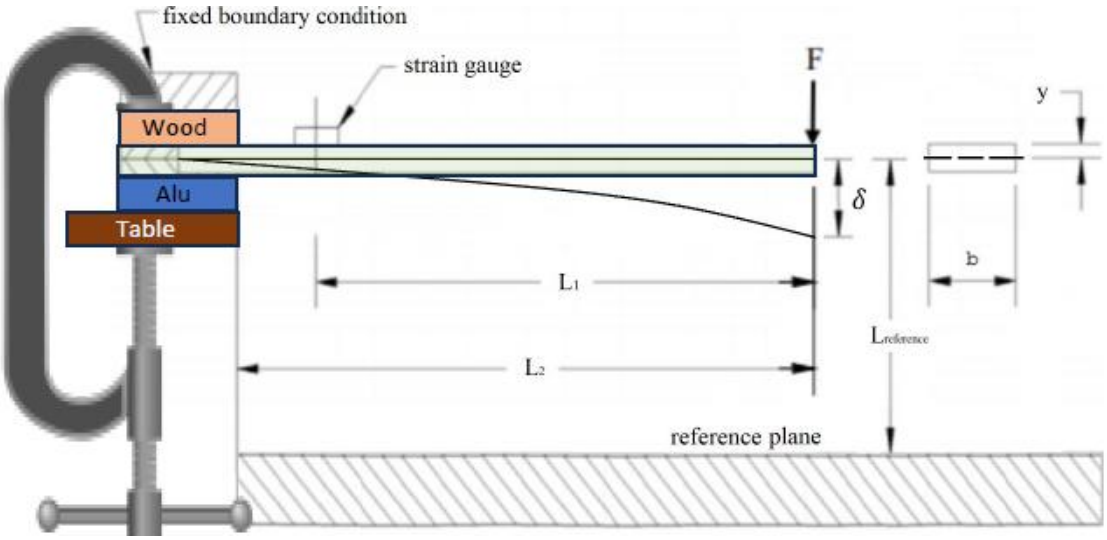


Figure 2: Experiment Set Up Instructions

Now that the student has set up the quarter bridge circuit as described in Figure 2 above, they proceed on to part 4 of the lab in which measurements are taken for actual beam deflection (at the tip) and voltage out of the quarter bridge circuit as weight is added to the tip of the beam. The student should be careful to take at least 3 measurements of each steady state condition voltage before moving onto the next condition (before adding more weight). However, only one

measurement is required for the initial condition of no weight added. Figure 3 below shows how a voltage measurement should generally look.

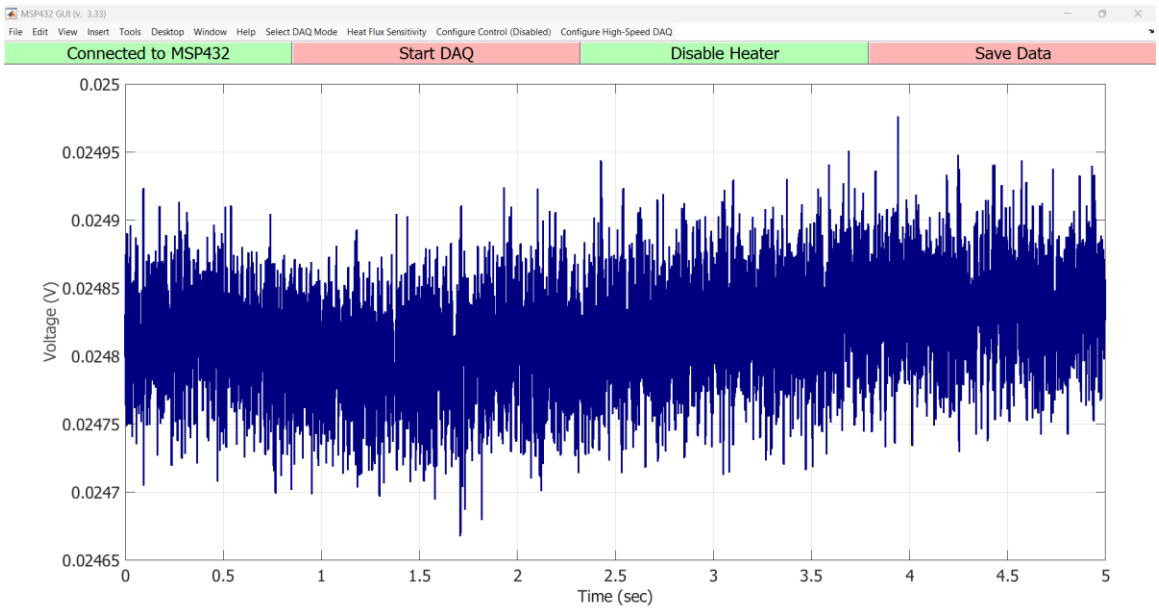


Figure 3: Example Voltage Measurement

Part 5 of the lab has the student utilize MATLAB to analyze the data collected [1].

Results and Discussion

Figure 4 below shows the relationship between applied stress and measured strain along with the linear line of best fit that was calculated from the data collected. Table 2 Below Figure 4 presents the statistical data for the calculated MoE.

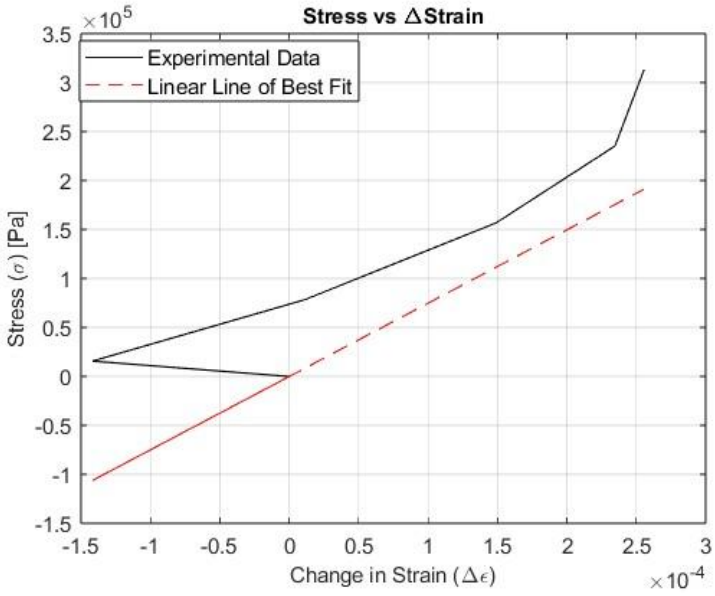


Figure 4: Stress vs Strain Plot

Table 2

μ MoE = 2.03 GPa	Upper Limit of 95% Confidence = 5.51 GPa	Lower Limit of 95% Confidence = -1.46 GPa

As seen above, the general trendline for the plot is as expected positive however the data has a likely errant value indicating negative strain with positive stress and as such the y-intercept for the linear line of best fit is negative which would generally not be expected for this type of plot. A generally accepted value for the MoE of pure aluminum is 69 GPa [2]. This is a little more than one order of magnitude larger than the calculated value which indicates an extreme level of experimental error. The most likely source for this error is therefore a human error while coding that resulted in something being wrongly multiplied or divided by a factor of 50. This would place the mean MoE at roughly 100 GPa which while higher than expected could be explained by normal experimental error sources such as resistor tolerance or slight differences between voltage outputs on the MSP432 units. Figure 5 below shows the calculated and measured tip deflection in relation to the applied load.

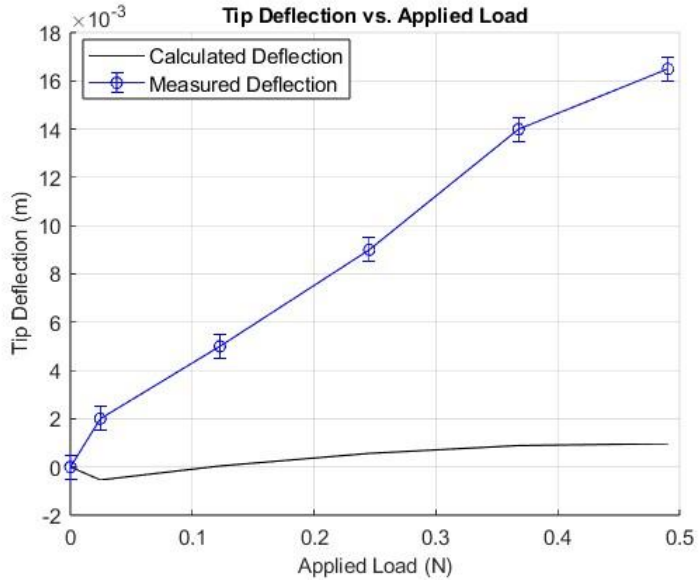


Figure 5: Deflection vs Applied Load from Measured & Calculated Data

The plot above shows a large difference between the measured and calculated values which supports the statistical data that shows a far lower MoE than expected. The calculated values show very little deflection which would be more expected from a higher MoE beam while the measured values are approximately an order of magnitude higher than the calculated values indicating a similar difference in actual MoE. Although the trend in the calculated values is difficult to see after the initial dip not seen in the measured values the trend does seem to be similar to the measured deflection where it increases steadily to a point then increases at a slower rate. The slope for the calculated values appears to also be roughly as compressed in relation to the measured values slope as the data points are. Prior condition of the ruler could also be to blame for the large differences found between measured values and the expected result for aluminum found online, however given the extreme difference of over an order of magnitude the most likely candidate for the discrepancy is human error.

References

[1] ME 4005 Course Materials. Available: https://canvas.vt.edu/courses/187828

[2] Bestech Australia, "Modulus of Elasticity - Young Modulus for some common Materials." Bestech Australia. [Online]. Available: https://www.bestech.com.au/wp-content/uploads/Modulus-of-Elasticity.pdf. [Accessed: Feb. 22, 2026].