# Using Strain Gages and Rosettes To Find Characteristics of Constant Stress and Cantilever Beams

Deep Patel*, Daniel Bouliga, Madelyn Hutton, Chad Gallop, Maame Assassie-Gyimah, Travis Spaulding, Bryce Franklin, Grishma Shah, Matt Jarvis
*Department of Mechanical and Aerospace Engineering*
*Rutgers University, Piscataway, New Jersey 08854*

**Single strain gages (and indicators) and strain gage rosettes are used to measure axial and transverse stresses in aluminum, brass, and steel beams. The change in output voltage due to resistance changes in the gages is used in its relation to strain to find the Young's moduli for these metals, which have been measured to be 7.29*10$^6$ psi for aluminum, 16.5*10$^6$ psi for brass, and 30.2*10$^6$ psi for steel. The Poisson's ratios for these metals are found to be 0.31 for aluminum, 0.34 for brass, and 0.30 for steel. The strain measured with a strain gage indicator is compared to the strain predicted by the multiple strain gage Wheatstone Bridge relationship. Lastly, a strain rosette is used to measure the change in strain upon a fixed change in deflection of the cantilever beam, which resulted in the discovery of the principal stresses in the beam. Results of the experiment indicate the validity of these stress-strain relations and demonstrate the use of strain gages in many similar situations.**

## INTRODUCTION

Strain gages have been used for a long time to give accurate and quick measurements for a variety of engineering and materials science purposes. Strain gages can be used in many ways, like in axial and transverse directions, and in a rosette formation, which can be used to find principal strains, principal angle, and principal stresses, all of which are very important in creating engineering parts and materials. These gages make it more convenient to measure local deformations due to applied loads.

Strain gages work by the change in resistance in the wire due to the deformation, which causes a change in output voltage across the gage. A Wheatstone bridge can be used by incorporating the gage in its varying part to measurement sensitive variances in voltage due to even small deformations.

This lab uses two types of beams, namely, constant stress beams (which vary in width to give equal stress as shown in Figure 1) and a cantilever beam as shown in Figure 2.

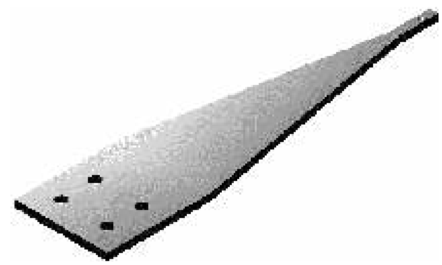

**Figure 1. Constant Stress Beam.**

**Figure 2. Cantilever Beam.**

Two different types of strain gage sensors as used in this laboratory. Two single axis strain gages are employed to measure both axial and transverse strain in constant stress beams of different metals. For better accuracy a strain gage indicator is also used. In the last section, a strain gage rosette is used to get the strains in different directions, which is shown in Figure 3.

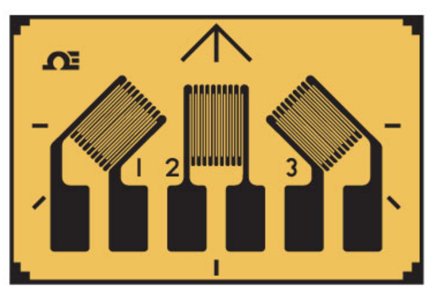


**Figure 3. Strain Gage Rosette**

* Corresponding Author

These strain gage elements measure the deflection/strain through the change in electrical resistance in relation to the gage factor (which is used to increase sensitivity or normalize results). Equation 1 shows this relationship.

$$\varepsilon = \frac{1}{F}\frac{\Delta R}{R} \qquad [1]$$

When a Wheatstone Bridge is used to measure the resistance change, the voltage is what is measured, so to find the resistance change, Equation 2 is used.

$$\frac{\Delta V}{V} = \frac{\Delta R/R}{4 + 2\Delta R/R} \qquad [2]$$

In the last part of the experiment, a strain rosette, which has 3 gages, as shown in Figure 3, is used and the principle strains can be found using geometry and Equation 3.

$$\varepsilon_{A,B} = \frac{\varepsilon_2 + \varepsilon_1}{2} \pm \frac{1}{\sqrt{2}}\sqrt{(\varepsilon_2 - \varepsilon_3)^2 + (\varepsilon_3 - \varepsilon_1)^2} \qquad [3]$$

With these principle strains, the principle stresses can be found with information about the Young's modulus of the material (E) and the Poisson's ratio (v) of the material using Equation 4 a & b. This can then be compared to the values that can be found using standard cantilever beam theory.

$$\sigma_A = \frac{E}{(1-\upsilon^2)}(\varepsilon_A + \upsilon\varepsilon_B) \qquad [4, 5]$$
$$\sigma_B = \frac{E}{(1-\upsilon^2)}(\varepsilon_B + \upsilon\varepsilon_A)$$

The axial stress in a constant stress beam is found by using Formula 6.

$$\sigma_x = \frac{6Px}{bh^2} \qquad [6]$$

For the second part, the flexural stress if found through the relations in Formula 7 & 8

$$F = \frac{3EI\delta}{L^3}, \quad \sigma_x = \frac{Fxc}{I} \qquad [7, 8]$$

Throughout the lab, hysteresis effects are accounted for through measurements of both loading and unloading of the beams.

## RESULTS AND DISCUSSION

The first part of the lab involved measurements of axial and transverse strain in constant stress beams of aluminum, brass, and steel. Loading of the beams went from 2.2 to 8.2 lbs and back down to account for hysteresis, which is shown in Figure 4.

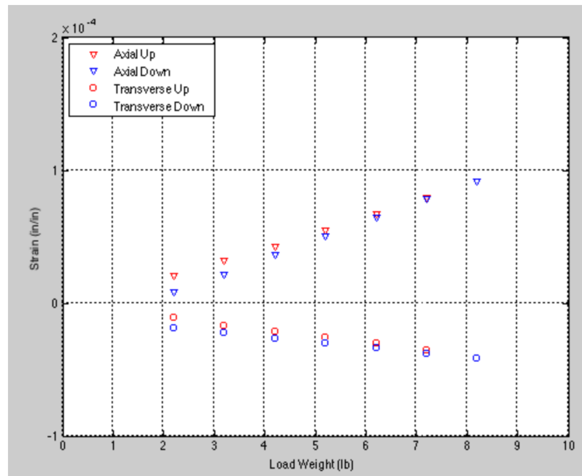


**Figure 4. Hysteresis Effect in Brass Axial and Transverse Strain Measurements**

Voltage was read from a zeroed Wheatstone bridge and equations 1 & 2 are used to find the axial and transverse strains; it can be seen that the strain increases linearly, but hysteresis effects are clearly present This is compared to the axial strain measurements using a Strain Gage Indicator. The measurements using the Wheatstone bridge were in agreement, but the SGI failed to get similar results. This may be due to improper setup with the position of the clamp holding the beam to the table. Nevertheless, they still show linear trends, which supports materials theory.

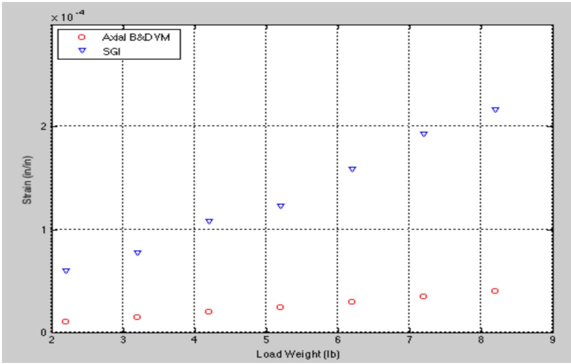


**Figure 5. Axial and transverse strain for a constant stress aluminum beam.**

Comparing the axial strain to the transverse strain gives the Poisson ratio. This relationship is plotted in Figure 6 and the negative slope of these lines give the Poisson ratios of the three metals. Due to the relatively high hysteresis error present in the apparatus, two ratios were found using both the loading measurements and unloading measurements and the average was taken to minimize the error and this gave fairly accurate values. The Poisson ratio for aluminum, brass, and steel is measured to be 0.31, 0.34, and 0.30, respectively. These values complement the theoretical ratios quite well, which are 0.33, 0.34, and 0.27-0.3 to aluminum, brass, and steel, respectively [1].

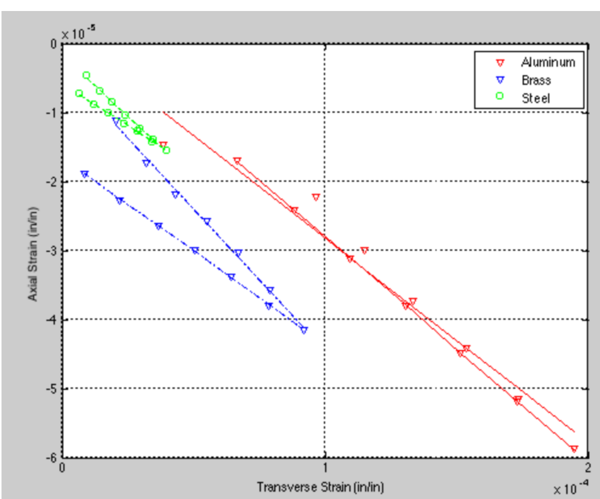


**Figure 6. Plot of axial strain vs. transverse strain to determine Poisson's ratio for 3 metals with loading and unloading strain measurements.**

Furthermore, using Formula 6, the axial stress in each constant stress bean was found and is shown varying along with strain in Figure 7. The slope of this graph gives the Young's (elastic) modulus of the metal.

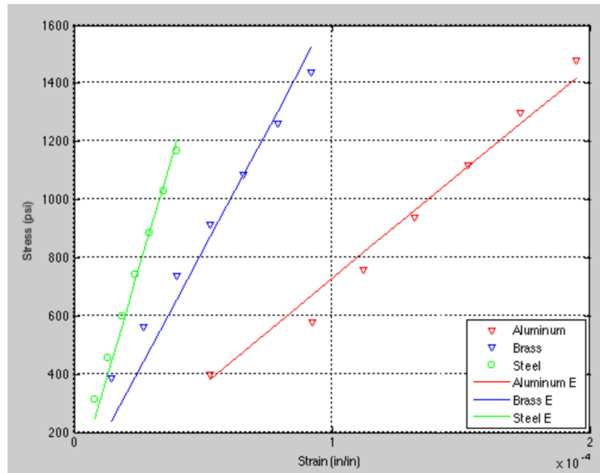


**Figure 7. Calculated axial stress vs. measured axial strain to determine Young's Modulus for 3 constant stress beams of different metals**

The calculated elastic moduli of aluminum, brass, and steel came out to be $7.3*10^6$ psi, $16.5*10^6$ psi, and $30.3*10^6$ psi, respectively. When compared to the theoretical values of $10*10^6$ psi, $16*10^6$ psi, and $30*10^6$ psi, respectively, the measured values of the modulus are in agreement with theoretical values [1].

The second part of the experiment focused on the cantilever beam that was deflected a certain amount (δ) using a micrometer and the coinciding strain was recorded on the three gages of the strain rosette (shown in Figure 2). Using these strain values of each gage, the principal strains are computed using Equation 3 and then the principal stresses are computed using Equations 4 and 5. This information is shown in Table 1. The principal stress and the calculated stress in the cantilever beam are quite similar.

**Table 1. Measured and calculated stresses and strains of a cantilever beam.**

| $\delta$ in | $\varepsilon_A$ in/in | $\sigma_A$ ksi | $\varepsilon_B$ in/in | $\sigma_{Cantilever}$ ksi |
|---|---|---|---|---|
| | meas. | calc | meas | calc |
| 0 | 7.59E-05 | 0.798 | -2.29E-05 | 0 |
| 0.1 | 2.33E-04 | 2.47 | -6.63E-05 | 1.83 |
| 0.2 | 4.27E-04 | 4.41 | -1.47E-04 | 3.65 |
| 0.3 | 5.58E-04 | 5.86 | -1.69E-04 | 5.48 |
| 0.4 | 7.53E-04 | 7.82 | -2.52E-04 | 7.31 |

## CONCLUSIONS

In this lab strain gages were used to measure the axial and transverse strain in several metals, namely, aluminum, brass, and steel. These strain measurements accounted for hysteresis and were used to obtain the Poisson ratio and along with the axial stress calculation using cantilever beam theory the elastic modulus of the metals is found. Using the strain gage indictor yielded measurements that did not match the strain measurements obtained with the single direction gage, Wheatstone bridge, and voltmeter setup, which could be due to the way the STI, was setup with the clamp.

For the cantilever beam, the principle stresses calculated using the strain rosette measurements and calculated principal stress values using the flexural formula were in good agreement.

**REFERENCES**

[1] Gere, J.M., *Mechanics of Materials,* 5th ed, Chapman and Hall, London, 2000.