LAB #5: Measurement of Strain

Equipment:

Multimeter & DC Power Supply
Balance Unit & Calibration Resistor
Strain Indicator (Measurements Group, Model P-3500)
Aluminum (Cantilever) Beam with Two Gages
Aluminum Tension Specimen with Two Gages
Load Frame and Load Cell

Objectives:

The purpose of this experiment is to acquaint you with the Wheatstone bridge circuitry used in strain measurement and with commercial strain-measuring equipment.

Introduction:

It is very important that resistance strain gages be mounted on the structure on which measurements are to be made in such a manner that the gages are strained in exactly the same manner that the structure is strained. To accomplish this, the gages are bonded to the structure using an appropriate bonding agent (adhesive). The technique for doing this is not complicated, but it requires very careful attention to details, meticulous cleanliness, and a considerable amount of practice. After the gages are mounted, lead wires must be connected to the gage tabs so the gages can be connected to a bridge circuit for taking strain measurements. The gage leads are attached to the gage by soldering, which is also an art that requires a great deal of skill.

Before starting to make measurements on either of the specimens on which strain gages have been previously mounted, closely examine the gage installation and the attached wires to make sure that the gage appears to be tightly bonded to the specimen, there are no scratches across the gage, the leads are securely soldered to the strain-gage tabs, etc. If you detect any possible difficulties with the specimen and gage, ask the TA if a different specimen is available.

Always record in your lab notebook any information that appears on the specimens (e.g., gage resistance, gage factor, etc.), on the load cell, etc.

1 Fundamentals of the Wheatstone Bridge Circuit, and its Application in Strain Measurement

1.1. Mount the aluminum beam with gages in the angle bracket on the load frame, as you did in Lab. 4. That is, mount it as a cantilever beam with the notch at the free end. Measure and record the resistance of each of the gages.

Gage # Gl ___________ Ω (top)
Gage # G2 ___________ Ω (bottom)

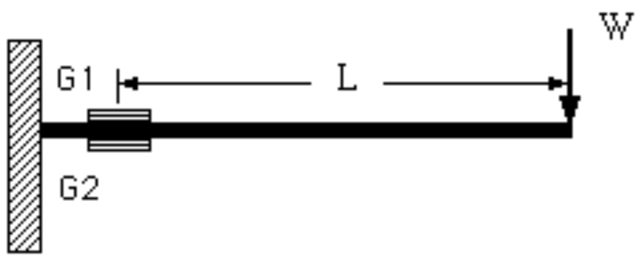

Figure 1: A Cantilever Beam with Tip Load

1.2. Make all physical measurements of the beam and loading weight that will be necessary for calculating the strain in the beam at the location of the gages when the weight is hung at the outer end of the beam. Record the data for future reference.

Beam:	Length	___________in. (moment arm to the center of gage)
	Width	___________in.
	Thickness	___________in.
	Material	___________
Weight:	Weight	___________lb

1.3. Sketch (in your lab notebook) a bridge circuit in which the two gages can be used to measure the strain in the beam when it is loaded as a cantilever beam. Use the arrangement that produces the maximum sensitivity.

1.4. Construct a bridge for strain measurement by connecting the lead wires of the gages to the balance unit. Complete the bridge using two of the three 120 Ω resistors provided. Label each bridge connection with the letter shown on the balance unit. Measure and record the input resistance to your bridge (across the INPUT terminals). Input resistance:_________Ω. Measure and record the output resistance of the bridge (across the OUTPUT terminals).

Output resistance:________Ω. These resistances should be about the same as the resistances of the gages you measured in Step 1.1.

Have your Instructor look at your setup before going further.

1.5. Turn on the DC power supply and use the multimeter to set its output voltage to 10V. Turn off the power supply, and then connect it to your bridge input terminals. Also, connect the multimeter to the bridge output terminals. Set the multimeter to read **DC voltage on the** 200 **mV scale**. Turn on the power supply.

1.6. Zero the output voltage of the bridge using the balance pot of the balance unit. Observe the output for at least one minute. Does it drift off zero? With your hand, deflect the end of beam about one inch. What change in the bridge output does this cause? Deflect the beam approximately the same amount in the opposite direction. How does this change the bridge output? When you allow the beam to return to its original position, does the output of the bridge return to zero? Now, hang a weight of about 1 kg (convert to pounds) on the end of the beam, and record the output voltage.

Output voltage at (__________lb load) = __________ mV.

Remove the weight. Does the output voltage return to zero?

1.7. Keeping the same setup, shunt one of the gages with a calibration resistor. Record the resulting output voltage.

Calibration Resistance __________ Ω

Output voltage __________ mV

1.8. Create a 1/4-bridge circuit by removing the lower gage from the bridge circuit and replacing it by a resistor of approximately the same resistance. Re-balance the bridge. Hang the weight on the beam again, and read the output voltage.

Output voltage at (__________lb load) = __________ mV.

Remove the weight from the end of the beam.

1.9. Hold your hand on the active gage (i.e., the one left connected to the bridge in Step 1.8) so as to warm it up; then observe the output voltage. What happens?

1.10. Turn off the power supply and un-wire your bridge circuit.

2 Use of the P-3500 Strain Indicator

Three bridge diagrams and the instructions for using the Strain Indicator are located inside the cover of the indicator. The instructions are reproduced, with some additional comments, in the following.

2.1. First, study the bridge diagrams carefully and take note on the meaning of posts (or nodes) P^+, P^-, S^+, and S^-. Note that the power is applied to the circuit across posts P^+ and P^-; the output signal is read from posts S^+ and S^-.

2.2. Connect gages. Set BRIDGE button to proper position (1/4, 1/2, or full bridge). (Note that the gages in the 1/2-bridge arrangement, as shown in the diagram, are in adjacent bridge arms. Therefore, **this 1/2-bridge arrangement** can be used for measuring the strain produced by a pure bending moment, but it **cannot be used to measure the strain produced by an axial load**!)

2.3. Depress AMP ZERO button. Set AMP ZERO control for reading of ± 0000.

2.4. Depress GAGE FACTOR button. Set GAGE FACTOR controls in accordance with gages in use. Lock GAGE FACTOR knob.

2.5. Depress RUN button. Set BALANCE controls for reading of ± 0000. Lock the BALANCE knob. Sometimes you cannot obtain a 0000 reading (i.e., the gage is over-strain). In this case, you need to record the reading. The measured strain is the difference between this reading and the reading taken when the specimen is loaded.

2.6. Load the specimen. The indicator should give you a reading. Note that the meter reads in units of microstrain ($\mu\epsilon$).

2.7. The CAL (calibration) button connects a $+5000\mu\epsilon$ (a pre-calibrated) shunt resistor across an internal dummy resistor.

2.8. BR EXCIT(ation voltage) OFF button removes excitation from bridge circuit.

2.9. MULT button extends measurement range to $\pm 199,990\mu\epsilon$.

3 Measurement of Strain in a Cantilever Beam

3.1. Connect the top (# G1) gage on the cantilever beam to the Strain Indicator using the indicated 1/4-bridge arrangement. Apply a 1 kg load to the end of the cantilever beam, as you did in Sect. 1, and record the strain using the tabular form below. Repeat the strain measurement using the bottom (# G2) gage in a 1/4-bridge arrangement.

	Gage # G1	Gage # G2
Initial reading (zero load)	____________	____________
1 kg load	____________	____________
Unloaded (zero load)	____________	____________

3.2. Repeat the strain measurement using both gages in a 1/2-bridge arrangement.

Initial reading (zero load)	____________
1 kg load	____________
Unloaded (zero load)	____________

4 Measurement of Strain in a Tensile Specimen

4.1. Obtain the prepared aluminum tensile specimen with two gages mounted on it. (This test specimen has a reduced cross section and has two reinforced holes for the loading pins.) Measure and record the cross-sectional dimensions of the bar at the gage location.

b (width) = __________ in.

t (thickness) = __________ in.

4.2. Using the load-cell wiring diagram on the testing frame, set up the load cell bridge circuit and balance it using strain-gage balance unit and using the multimeter to read the output. Note that the input voltage to the load cell is +10 V. The output of the multimeter should be set on the **lowest DC voltage scale (200 mV)**.

The load capacity of the load cell is 3,000 lb, and the rated output is 3 mV/V. For a 10 V excitation voltage, the output at rated load is 30 mV. Thus, a change in the output voltage of 1 mV corresponds to a load increment of 100 lb. A schematic of the load cell is attached as an appendix.

4.3. Using two steel pins, mount the tensile specimen in the load frame. Connect the lead wires of the # G1 gage to the Strain Indicator using a 1/4-bridge arrangement, and prepare the indicator by following the instructions in Sect. 2.

4.4. Be sure that the multimeter is set on the 200 mV scale. Apply a load of 1000 lb (10 mV on the multimeter) to the specimen. **DO NOT OVERLOAD THE SPECIMEN OR THE LOAD CELL!**

4.5. Measure and record the strains, using first the # G1 gage, and then the # G2 gage.

	Gage # G1	Gage # G2
Initial reading (zero load)	______	______
1000 lb load	______	______
Unloaded (zero load)	______	______

4.6. Repeat the strain measurement using both gages in a 1/2-bridge arrangement. Re-read Section 2.2, noting that you can't just connect the gages on the tensile specimen as a 1/2-bridge on the Strain Indicator. Use the full-bridge arrangement and use the two 120 Ω gages on the cantilever beam specimen to complete the bridge.

Initial reading (zero load)	______
1000 lb load	______
Unloaded (zero load)	______

Some Topics for Inclusion in Formal Report 2

1. Sketch the following:
   (a) the half-bridge Wheatstone bridge circuit of Step 1.3;
   (b) the P-3500 Strain Indicator circuit of Step 3.2; and
   (c) the P-3500 Strain Indicator circuit of Step 4.6.
2. Using the data you obtained in Steps 3.1 and 3.2, compare the average strains you measured using 1/4-bridge arrangements to the strain you measured using a 1/2-bridge arrangement. What are the relative advantages and disadvantages of these bridge arrangements?
3. Calculate the expected (theoretical) strains from the tension and bending tests and compare these strains to the measured strains. Record the results in appropriate tabular form, and briefly explain any discrepancies.

Appendix:

CHY(L6); Revised 10/94, 10/97, 4/98, 10/00, pdf 1/01; RRC.