Lab 5 - Strain Gages

Format
This lab will be conducted during your regularly scheduled lab time in a group format. You may ask the lab instructor for assistance if needed, but successful completion of the lab is your responsibility.

Report
An individual, informal lab report is due from each student by 8:00 AM on the Friday of the week after you complete this lab. This short report does NOT need to follow the formal report format described in the ME 360 course manual. All of the information specifically requested in this lab handout must be present in your report. The printed report must be stapled in the upper left-hand corner and should not be bound in any other way.

Procedure - Strain Gage Installation and Testing
Each team of 2 or 3 students will install two gages on a single cantilever beam. Be sure to rotate roles throughout the lab so that each student becomes familiar with the strain gage installation process. The process for testing the cantilever beam is described below.

1. Determine the approximate position of the cantilever beam in the mount and the longitudinal location of the strain gages.
   - The strain gages should be approximately 3 to 5 beam widths away from the mount or edge of the table.
   - There should be approximately 15 to 24 inches of beam between the strain gage and the hole provided for attaching the load weights.
   - Measure and record the distance, $x$, from the center of this hole to the center of your strain gages. This value will be used in your calculation of bending stress/strain.
   - Estimate the uncertainty, $U_x$, in your measurement based on the technique and measurement system used.

2. Measure and record the beam dimensions using the calipers and/or micrometer provided.
   - Since the beam is not completely uniform, measure width, $w$, and thickness, $t$, in at least 10 locations along the beam between the clamp mount and strain gage location.
   - These repeated measurements of (supposedly) identical values will be used to determine the precision uncertainty in width ($U_w$) and thickness ($U_t$).

3. Record the model, resistance, and gage factor, $F$ (and its uncertainty, $U_F$) of the strain gages. This information is supplied on the data sheet that comes with the strain gages.

4. Install both gages on the beam so that the long axis of the gage corresponds to the long axis of the beam. Refer to the Strain Gage Installation with M-Bond 200 Adhesive handout for installation instructions (see lab notebook). These gages are to be placed on opposite sides of the beam (at the same longitudinal location) such that one is tension and the other in compression during loading.

5. Solder the stranded lead wires to the gages. Tape the leads to the beam to minimize the chance of pulling the wires from the gages. Measure the resistance of the gages at the ends of the stranded lead wires after soldering to verify proper installation.
If you measure an open circuit, one of the solder connections is loose or detached. If you measure a very low resistance (fraction of an ohm), then you have a short circuit.

6. Connect the strain gages to adjacent legs in a half-bridge arrangement, as shown in Figure 1. Use 348Ω resistors for the other two legs of the bridge, since 350Ω resistors are not standard. Use a power supply \( V_{in} \) of nominally +12 volts DC. Use a 10kΩ, 50kΩ, or 100kΩ potentiometer (larger is better) to "zero" the output \( V_{out} = 0 \text{ mV} \) of your bridge with no applied load.

7. Mount the beam on the table with the supplied clamp.
   - Measure the cantilevered length, \( L \), of the beam and the longitudinal location of the strain gages using the tape measure.
   - Note that lengths are measured to the center of the mounting hole provided for the load weights, not to the tip of the beam.

8. Measure the bridge input voltage \( V_{in} \). It is a “good idea” to measure \( V_{in} \) periodically throughout the experiment to determine if supply voltage drift has occurred.

9. Compute the design load \( P_{design} \) that would create a bending stress of 12 ksi at the base of the cantilevered portion of the beam.
   - Select weights available in the lab such that 8 to 10 approximately equal weights add up to a value in the range of \( P_{design} \) to 2\( \cdot P_{design} \).
     - These weights should be roughly the same, don’t use two or three very large and six or seven very small weights.
   - Measure and record the value for each weight.

10. Read the bridge output voltage \( V_{out} \) with no load on the beam. If \( V_{out} \neq 0 \text{ mV} \), use the potentiometer to “zero” the bridge, i.e., make \( V_{out} = 0 \text{ mV} \).
11. Add an individual weight to the beam and record the load, $P_{\text{actual}}$ (total applied weight), and bridge output voltage $V_{\text{out}}$.
   - Use a millivolt (mV) setting on the DMM.

12. Continue adding weights and recording the load, $P_{\text{actual}}$ (total applied weight), and bridge output voltage $V_{\text{out}}$ for all 8 to 10 beam loads.
   - You should end with all 8 to 10 of your loads applied to the beam.

13. Remove the weights and re-zero the bridge output, if needed. Repeat the previous two steps at least one more time, with different students applying loads and recording the data.

14. Remove the threaded rod hanger from the end of the beam and use the wire/washer combination provided by the lab instructor. Repeat steps #10 to #12 two more times with the same weights used earlier. You should end the experiment with 4 sets of data with 8 to 10 loads in each data set.

**Outside of Lab:**

15. For each load $P_{\text{actual}}$ (total applied weight), calculate the maximum bending stress and the bending stress at the strain gage. Compare these values to typical yield strength values for structural aluminum (typically 6061-T6 or 7075-T6).

16. For each measured value of output voltage $V_{\text{out}}$, calculate a theoretical load ($P_{\text{theo}}$) value using the stress/strain formulas, measured dimensions of the beam, and the appropriate Wheatstone bridge equation.

17. Determine the uncertainties in your theoretical loads, $U_{P_{\text{theo}}}$.
   - The theoretical value for load will have uncertainty since measured parameter values ($t$, $w$, $V_{\text{out}}$, etc.) were used in the theoretical calculation.

18. Plot theoretical/calculated load $P_{\text{theo}}$ vs. actual applied load $P_{\text{actual}}$ using both sets of data for the threaded rod case. Include uncertainty ("error bars") for theoretical/calculated load $P_{\text{theo}}$. Include an ideal line where theoretical/calculated load equals actual applied load. Discuss any discrepancies.

19. Repeat all steps above using both sets of data for the wire/washer case.

20. Do all of the theoretical loads, $P_{\text{theo}} \pm U_{P_{\text{theo}}}$ overlap the actual loads, $P_{\text{exp}}$? If they don’t, why not?

21. What can you conclude about strain gages from this experiment?

22. What can you conclude about the two different methods for loading the beam (threaded rod vs. wire/washer)?

*Use good engineering judgment in answering all questions.*