

# MCE380: Measurements and Instrumentation Lab

## Strain Gages and Young's Modulus Measurement

In this experience, groups will be practicing strain gage mounting and signal analysis techniques. The techniques will be used to find the elastic modulus ( $E$ ) of an unknown material. This lab also reviews statistical data analysis as applicable to determine confidence interval for  $E$  and the density.

**Many operations in this lab are delicate and require concentration, neatness and attention to detail. Negligence will result in wasted strain gages, fried electronics and a corresponding grade. If you're not "handy" just watch from a safe distance (safe for the rest of us) and help later with the report. In the lab:**

1. Take 8 measurements of beam width and length using a caliper. Do the same for the thickness, but using a micrometer.
2. Take 8 measurements of beam mass using the scale.
3. The beam will be mounted as a cantilever using the provided support. Reserve about 3/4" of beam length for securing it to the support and plan to attach the strain gage about 1/4" from the 3/4" line. Clean the area where the gage will be attached with fine sandpaper and acetone. Remove any debris with a lint-free cloth.
4. Carefully attach the strain gage to the beam using cyanoacrylate (super glue). Wire connections must be on top of the gage and away from the beam support. Do not glue your fingers to the beam!!. Work carefully, so that the strain gage is parallel to the length of the beam.
5. Pay close attention to the following: the exposed copper near the gage is not allowed to short across the beam metal. Use tape or other non-conducting material so that the wires don't touch the beam.
6. Mount the beam and secure the wires to the beam support with tape. **The instructor will assign part of the lab grade on the basis of the final quality of the strain gage installation. You will be informed about a 0-5 score for this, 0 being the lowest.**
7. Measure the free length of the beam once and the distance from the fixed end to the middle of the strain gage once. Write down these values.
8. You will be using a bridge completion module (BCM) to connect the strain gage.
9. **Ask the instructor about the particular gage factor and gage resistance values.**
10. Make the following connections (see instruction booklet): one strain gage lead to +SIG, the other to +BRG. There is no polarity (the strain gage is just a resistor). Then connect a short jumper wire between +SIG and 120.
11. Adjust the power supply to provide 5VDC to the BCM. Connect supply ground to Excitation - and +5 V to Excitation +. Check the power supply voltage with the multimeter before connecting to the BCM.

12. Check the output voltage with a multimeter. It should be small (in the mV range). Zero-out this reading using the screw.

**LabView users only:**

1. Create an analog voltage input channel with differential mode. Use the AIN+ and AIN- connections to hook up the BCM output. You will have to iterate with the range, but use -5 V to +5 to start. Use a 1k sample rate with 100 samples to read.
2. Verify that the readings shown on the LabView interface match what is measured with the multimeter.
3. Build a VI to translate the voltage from the BCM to microstrains. Use the formulas at the end of this guide. Include a zeroing function.

**All:**

1. Push the beam gently to either side and check for consistent voltage readings. Use the zeroing screw on the BCM or the LabView slider to obtain zero volts for zero deflection.
2. Use the screw to apply a constant, known deflection to the beam. Write down the deflection and its location along the beam, along with the voltage. If using LabView, call the instructor for verification of the displayed strain value. Write down the strain indicated by LabView.
3. Remove the deflection and check that the voltage is approximately zero. If not using LabView, connect the oscilloscope leads to the output. Let the beam vibrate freely by flicking it with your finger. Set the oscilloscope to a timebase between 50 and 250 ms, as appropriate to display the vibrations of the beam. Adjust the vertical scale so that all of the oscillations are visible.
4. Practice flicking the beam and stopping the oscilloscope to display about 10 vibration cycles.
5. When you have obtained a nice snapshot of the vibrations, use the CompactFlash card to store the trace.
6. If you used the flash card, use the reader attached to one of the PCs to save the data to your memory stick. Check the integrity of the data by opening the file using a spreadsheet or Matlab.
7. If using LabView, perform the above steps using a waveform graph. Save the data and check that you can import it into Matlab.

**At home:**

1. Calculate the volume of the beam and then the density using the 8 data points. Report the densities in kg/m<sup>3</sup>.
2. Use the vibration trace to determine the oscillation frequency  $w_d$  in rad/s. Also, use the ratio between two vibration peaks to determine the logarithmic decrement:

$$\delta = \frac{1}{n} \ln \frac{x_0}{x_n}$$

where  $x_0$  and  $x_n$  are  $n$  peaks apart, with  $x_0 > x_n$ . Then find the damping ratio:

$$\zeta = \frac{1}{\sqrt{1 + \frac{2\pi^2}{\delta}}}$$

- Determine eight values of resonant frequency with the formula

$$w_1 = \frac{w_d}{\sqrt{1 - \zeta^2}}$$

- Use the following formula to find  $E$

$$E = \frac{\rho A w_1^2}{I k^4}$$

where  $A$  is the cross-sectional area,  $I$  is the moment of inertia with respect to the neutral axis,  $w_1$  is the first resonant frequency and  $k = 1.875$ . Find 8 values of  $E$  in GPa. **Be extra careful with units!**

- Use the 8 values of  $E$  and the 8 values of  $\rho$  to find a 95% confidence interval for the elastic modulus and density.
- Based on the above values, do a search for candidate materials and try to identify the beam material (brass, copper, steel, burlap?)
- After you've found the modulus of elasticity, use a beam formula to find the strain corresponding to the constant deflection applied earlier and compare it with the value calculated from the BCM output.

### Report:

Write a short but complete report. Focus on presenting input data, showing the calculations and then presenting processed data and conclusions. **DATE DUE: Consult schedule posted in course website or check with instructor**

## 1 Formulas

Strain:

$$\epsilon = \frac{1}{F} \frac{\Delta R}{R}$$

$F$  is the gage factor and  $R$  is the resistance of the gage. Change in resistance from Wheatstone 1/4 bridge:

$$\frac{\Delta R}{R} = \frac{\left(\frac{\Delta E_D}{V} + \frac{1}{2}\right)}{1 - \frac{\Delta E_D}{V} - \frac{1}{2}} - 1$$

where  $\Delta E_D$  is the voltage output from the BCM and  $V$  is the excitation voltage (5V in this case).