#### **Static Strain Measurement (Cantilever Beam)**

#### **Objectives:**

- Learn about the use of resistance strain gages and Wheatstone bridges
- Learn to use a static strain indicator
- Practice the application of Uncertainty Analysis to a physical situation

#### Introduction

Strain gauges are used as sensors in many systems to measure forces, moments, and the deformations of structures and materials. This experiment deals with measuring the strain in a cantilever beam through the use of four resistance strain gages; two mounted on top of the beam and two mounted below. A static load will be incremented at different locations along the beam to produce measurable strains. The theoretical strain can be found using Equations 1 and 1a.

$$\epsilon = \frac{Mc}{IE} \tag{1}$$

$$I = \frac{bh^3}{12} \tag{1a}$$

Where:

 $\epsilon$  is the strain ( $\mu$  m/m)

M is the moment (Force (N) x Length (m))

c is the distance from the center of the beam to the point where the strain is being measured (h/2 in this case) (mm)

*E* is the modulus of elasticity  $(210 \text{ kN}/\text{mm}^2)$ 

b is the width (mm)

h is the thickness (mm)

The stress at the surface of the bending beam can be calculated from the bending moment  $M_b$  and the sectional modulus  $W_v$ . The stress is given by

$$\sigma = \frac{M_b}{W_y} \tag{2}$$

The bending moment is given by

$$M_b = -F \cdot L \tag{3}$$

The sectional modulus for the rectangular section of width b and height h is

$$W_y = \frac{b \cdot h^2}{6} \tag{4}$$

The stress calculated with equation (2) can also be compared to the stress calculated from the measured strain via Hooke's law:

$$\sigma = \epsilon \cdot E \tag{5}$$

In this experiment, you will use a beam with four strain gauges pre-attached and wired to form a four active leg Wheatstone bridge. The Gunt FL100 measurement amplifier reads the Wheatstone bridge and outputs the strain as  $\frac{mv}{v}$ . By adjusting the weight mounting point, three different beam lengths will be tested in this experiment.

Converting from  $\frac{mV}{V}$  to strain is very straightforward. The equation for the conversion is

$$\epsilon = \frac{1}{k} \cdot \frac{mV}{V} \cdot 10^{-3} \frac{V}{mV}$$

k is the gauge factor and for this equipment is

k = 2.05

Beam Data:

Length: 385 mm Width: 20 mm Thickness: 5 mm

# <u>Equipment</u>

- Gunt strain gauge measuring amplifier
- Gunt loading frame
- 1-6 N, 0.5 N graduation weight set
- Clamped steel cantilevered bean with attached 4 active leg strain gauges
- Connecting cables
- Large and medium vernier calipers
- Allen wrench to adjust effective beam length

# **Procedure**

1. Remove the cantilever beam from the storage container and mount it on the two metal pins on the left side of the loading frame.

2. Using the calipers and Allen wrench, adjust the position of the weight mount so that the center of the weight mount to the front face of the perplex housing around the strain gauges is the length listed for experimental run 1 in the table below. The 38 mm that is being subtracted is the distance from the center of the strain gauges to the front face of the perplex housing.

Experimental Run	Length (mm)
1.	150 - 38 = 122
2.	200 - 38 = 162
3.	250 - 38 = 212

- 3. Connect the data cable between the strain gauge amplifier and the port on the back of the cantilever beam.
- 4. Power up the strain gauge amplifier (switch is on back by power cable)
- 5. After unit initializes, use the multi-turn potentiometer on the front of strain measurement amplifier to zero out the display. This balances the Wheatstone bridge.
- 6. Hang the EMPTY weight hanger on the hook. After the display stabilizes, record the strain displayed in the table below.

Beam Length: 150 mm		
Weight (N)	Strain (mV/V)	
1.0 N (empty hanger)		
1.5 N (one weight on hanger)		
2.0 N		
2.5 N		
3.0 N		
3.5 N		
4.0 N		
4.5 N		
5.0 N		
5.5 N		
6.0 N		

- 7. Power off the strain measurement amplifier and remove all weights and the weight hanger.
- 8. Using the calipers and Allen wrench, adjust the position of the weight mount so that the center of the weight mount to the front face of the perplex housing around the strain gauges is the length listed for experimental run 2 in the table above.
- 9. Repeat steps 4 through 6 and record the data in the table below

Beam Length: 200 mm		
Weight (N)	Strain (mV/V)	
1.0 N (empty hanger)		
1.5 N (one weight on hanger)		
2.0 N		
2.5 N		

3.0 N	
3.5 N	
4.0 N	
4.5 N	
5.0 N	
5.5 N	
6.0 N	

- 10. Power off the strain measurement amplifier and remove all weights and the weight hanger.
- 11. Using the calipers and Allen wrench, adjust the position of the weight mount so that the center of the weight mount to the front face of the perplex housing around the strain gauges is the length listed for experimental run 3 in the table above.
  - Beam Length: 250 mm

     Weight (N)
     Strain (mV/V)

     1.0 N (empty hanger)
     1.0 N (empty hanger)

     1.5 N (one weight on hanger)
     2.0 N

     2.0 N
     2.5 N

     3.0 N
     3.5 N

     4.0 N
     4.5 N

     5.0 N
     5.5 N

     6.0 N
     6.0 N
- 12. Repeat steps 4 through 6 and record the data in the table below

- 13. Power off the strain measurement amplifier and remove all weights and the weight hanger.
- 14. Replace the weight hanger in the storage container.
- 15. Disconnect the data cable and replace it in the storage container.
- 16. Remove the bending beam assembly and replace it in the storage container.

# The Results

Now you are ready to write a report using the format prescribed. Here is a brief outline of what your report should contain and below are some questions you should try to answer indirectly in your report.

# **Report Outline**

Title Page Table of Contents Table of FiguresTable of TablesList of tables of collected data

Abstract General description of the report

# Introduction

Expand on the abstract. Wheatstone bridge is used to measure the strain gauges.

### Theory

Strain and deflection theory as well as pertinent Wheatstone bridge theory and an introduction to the uncertainty analysis you will be doing.

# **Experimental Setup**

Picture and brief description

# Procedure

This should describe what you did to run the experiment

### Data

All that was collected

#### Results

# NOTE: ALWAYS show a sample calculate for EVERY calculation. Then tabulate all the results into an appropriate table.

Show strain versus force plots of the data. One figure with three plots is appropriate. Show the relevant plots of the calculated stress. Three figures, one for each beam length, with two plots each.

Calculate the percent error in measured versus calculated strains.

Calculate the percent DIFFERRENCE in stress calculated from equations (2) and (5) Perform Uncertainty Analysis for the 250 mm beam with 6.0 N loading.

### **Report Questions**

NOTE: As before, make sure these questions are discussed IN the results section.

- 1. Give reasons for the values of percent error in the strain calculations.
- 2. Ditto for the stress calculations.
- 3. What conclusions can you make based on your uncertainty Analysis for the beam?

# Conclusions

### References

# Lab Reactions

(This information is for the grader. It is not technically part of a technical report so include it on its own page as the last page and it does NOT count towards the report page length) – A brief explanation of what you learned in this lab. No more than half a page.