

AME 21241 Laboratory 3: Beam Bending and Strain Transformation

Introduction

Beams are structural elements used to carry loads transverse to their length. They carry loads by bending. They are used in many engineering designs such as buildings, cars, airplanes, and bridges. In this laboratory exercise you will measure the bending strains in two 6061 aluminum I-beams using strain gages. You will then use this information to calculate the stresses that correspond to the measured strains. In your calculations, take the elastic material properties of aluminum to be: $E = 10 \times 10^6$ psi and $\nu = 0.3$.

The experiments will be performed on standard S3x1.99 aluminum I-beams (Fig. 1). The cross-sectional dimensions of the beams are determined by industry standards, and can be found in tables provided by manufacturers and other standards organizations.

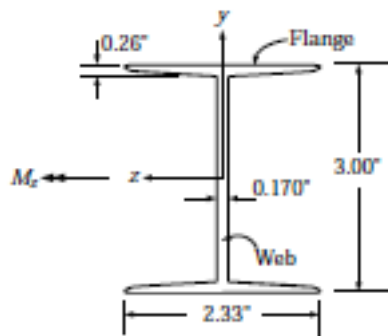


Figure 1: Cross-section of the I beam used in the laboratory.

You will study two cases in this exercise, three-point bending (Fig. 2a) and four-point bending (also called pure bending) (Fig. 2b). As you can see, these names are very descriptive of the way the beams are loaded. It is assumed that you know how to find the shear force and bending moment in a beam. The discussion here is restricted to linear elastic materials. Beams, like other structural members, resist loads by deforming, which gives rise to strains and stresses in the material.

Equipment

- ATS Testing Machine
- Strain Gages (350 Ohm)
- Strain Indicator

Objectives

1. To demonstrate the use of strain gages and associated instrumentation in experimental stress analysis.
2. To measure stresses in beams and compare them to the calculated moment and shear force acting on the cross-section of the beam.

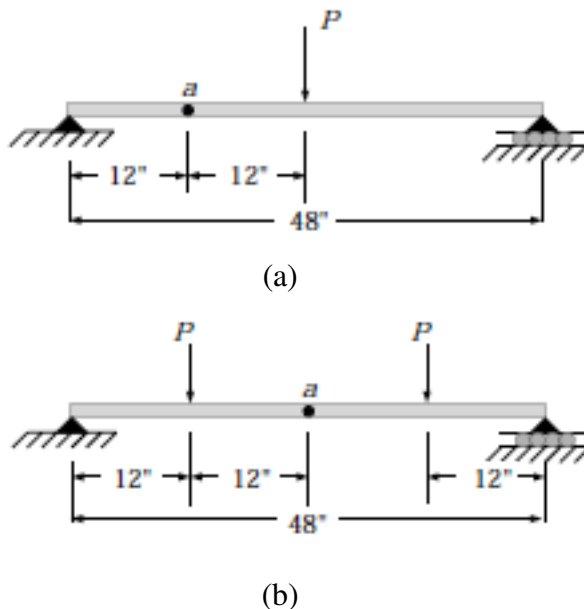


Figure 2: (a) Three-point bending (b) Four-point bending

Instrumentation

Both beams to be tested have been instrumented with strain gages. The placement of the gages on the beams is the same in both beams. Two uniaxial strain gages on one flange, one uniaxial strain gage and one 45° strain rosette on the other flange, and another 45° strain rosette at the center of the web of the beam. In the three-point bending test, the strain gages are located at 1/4 of the span while in the four-point bending test they are located at mid-span (Fig. 2). The gage factors are:

- Uniaxial gages, 2.15
- Rosettes
 - Inclined gages, 2.125
 - Center gage, 2.155

The instrumentation used to measure strain will be very similar in each set-up. In each test, you will be using a power supply/bridge unit. They operate in slightly different manners, but both display strain directly in units of micro-strain (assuming you input the correct strain gage and operate them carefully).

Procedure

The steps to perform the experiment are listed below. If you have questions, ask your TA. One group will start with the three-point bending test while the other will start with the four-point test and then exchange set-ups.

Four-point bending test

1. Draw a sketch of the location of the strain gages on the beam. Identify the strain gages by the color of the small piece of tape next to them. The lead wires have also been color coded for convenience. Pay attention to the orientation of the rosettes. Note that for the rosettes, the black and red wires are attached to the inclined gages while the white wires are attached to the center gage.
2. The strain indicator is used to measure strain; it performs the calculation from the voltage automatically.
3. Record which gage is connected to each channel.
4. Make sure that the beam is totally unloaded by observing that it is not making contact with the upper semi-circular loading points.
5. Align the beam with the loading points.
6. Make channels 1 to 4 on boxes 1 and 2 active
 - a. Press the “Chan” button
 - b. For each channel
 1. Use the up/down arrow key to select desired channel
 2. Press right arrow key until “active” is displayed.
 - c. Press “MENU” button

7. Make channel 1 on box 3 active using the above procedure. Disable channels 2-4.
8. Set all active channels to quarter bridge
 - a. Press “bridge” button
 - b. For each channel
 1. Use the up/down arrow key to select desired channel
 2. Press right arrow key until “quarter” is displayed.
 - c. Press “MENU” button
9. Set gage factor for all channels
 - a. Press “k” button
 - b. For each channel
 1. Set channel number using right arrow
 2. Use down arrow to highlight “gage factor”
 3. Press right arrow to select digit
 4. Press up/down arrow to set digit
 5. Press right arrow to move to next digit
 6. Press left arrow to move cursor into first column
 - c. Press “MENU” button
10. Press balance key twice. Do not save values.
11. Zero the output of the load cell.
12. Now, slowly move the lower crosshead up until contact is made and the load starts changing. Continue moving the crosshead up at a rate of 0.050 in/min. Stop when the load reaches approximately 1000 lbs. Press the stop button when the desired load is reached.
13. Record the load and the strain output for each channel.
14. Repeat steps 12 and 13 for increments of approximately 100 lbs up to a maximum load of 2000 lbs. DO NOT load the beam above 2200 lbs.
15. Release the load in the beam by moving the lower crosshead down.

Three-point bending test

1. Draw a sketch of the location of the strain gages on the beam. Identify the strain gages by the color of the small piece of tape next to them. The lead wires have also been color coded for convenience. Pay attention to the orientation of the rosettes. Note that for the rosettes, the black and red wires are attached to the inclined gages while the white wires are attached to the center gage.
2. The instrumentation consists of two boxes. One is the strain indicator and the other is the switch-and-bridge unit. The strain indicator is used to measure strain; it performs

the calculation from the voltage automatically. The other unit is used to balance the bridges and select the channel to be measured by the strain indicator.

3. You will note that one of the knobs on the strain indicator is labeled as “gage factor.” This is where you let the instrument know the gage factor. Read the dial to see where it is set. Set it to the range of 1.8 – 2.4.
4. Record which gage was connected to each channel on the switch unit.
5. Make sure that the beam is totally unloaded by observing that it is not making contact with the upper semi-circular loading point.
6. Align the beam with the loading points. The black mark near one end of the beam must be on top of one of the loading points.
7. Balance each bridge in the switch and balance unit so that the strain reading is zero in all nine channels. If it is not possible to zero all channels, note the values of any that are non-zero. Record the balanced output of each bridge. This is the zero strain reference.
8. Zero the output of the load cell.
9. Now, slowly move the lower cross-head up until the load starts changing. Continue moving the cross-head up at 0.050 in/min until the load is 500 lbs. Press the stop button when the desired load is reached. Do not load the beam above 1200 lbs.
10. Record the load and the strain output for each channel.
11. Repeat steps 9 and 10 for increments of approximately 50 lbf until you reach a load of approximately 1000 lbf. Do not load the beam above 1200 lbf.
11. Release the load in the beam by moving the lower cross-head down.
12. Once again, read the output of each channel to make sure that the zero strain reference has not changed. If it has changed by more than 10 microstrain, you need to repeat the measurement for that channel.

Report Guidelines (Note: Review Section 8.10 in the text ahead of time for information on strain rosettes, pages 565-567 and Eqns. 8.50 to 8.54)

For each beam:

1. Draw the shear force and bending moment diagrams for each bending case as a function of the applied load P. Clearly label the values of shear force and bending moment at the gage location. Calculate the shear force and bending moment for each load you applied in each beam.
2. Calculate the strains measured by the single, linear gages.
3. Calculate the strains, ϵ_x , ϵ_y and γ_{xy} , in the web, and ϵ_x , ϵ_z , and γ_{xz} , in the flange using the rosette data.
4. Calculate the stresses – i.e. σ_x , σ_y and τ_{xy} or σ_x , σ_z , and τ_{xz} from the measured strains from both the rosettes and the linear strain gages.
5. Plot σ_x in the top flange, bottom flange, and in the web as a function of bending

moment for both beams. How is the longitudinal stress in a beam at each location related to the moment?

6. In your discussion, note how the stresses along the axis of the beam (in the x direction) in the top and bottom flanges and in the web differ. Based on this data, and the fact that the *resultant axial force* on the beam is zero, suggest a possible relationship between the stresses at equal distances above and below the center of the beam (keep it simple!). What parameters other than the applied moment and the distance from the center of the beam might affect the stress?

We will review the answers to these questions in class later in the semester. Do not be concerned with getting the correct answers at this point. Just give reasonable answers and back them up based on what you know from the class (or other classes) so far.

7. Plot the shear stresses, τ_{xy} , in the web and τ_{xz} in the flanges as a function of the shear force. How is the shear stress in the web and flange of the beam related to the applied shear force? What parameters other than the applied shear force might affect the shear stress in the beam?

APPENDIX 1: Color Code for Strain Gage Channels

4 POINT			
BOX-CHANNEL	COLOR	SUB-COLOR	TYPE
1			
1-1	BLUE		
1-2	RED		
1-3	YELLOW	BLACK	INCLINE
1-4	YELLOW	RED	INCLINE
2-1	YELLOW	WHITE	CENTER
2-2	GREEN	WHITE	CENTER
2-3	GREEN	RED	INCLINE
2-4	GREEN	BLACK	INCLINE
3-1	BLACK		

3 POINT			
BOX CHANNEL	Color	Sub-Color	Type
1-1	BLUE		
1-2	BLACK		
1-3	RED		
1-4	YELLOW	BLACK	INCLINE
2-1	YELLOW	RED	INCLINE
2-2	YELLOW	WHITE	CENTER
2-3	GREEN	BLACK	INCLINE
2-4	GREEN	WHITE	CENTER
3-1	GREEN	RED	INCLINE

Appendix 2: Image of a 45° rosette strain gage

