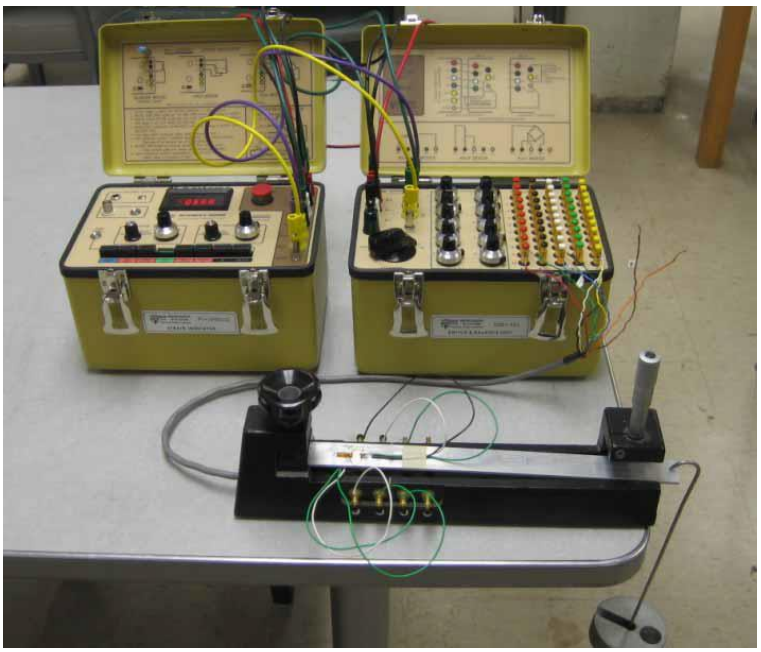
Experiment Five (5)
Principal of Stress and Strain

Introduction

Objective: To determine principal stresses and strains in a beam made of aluminum and loaded as a cantilever, and compare them with theoretical values.

Apparatus:

1. Cantilever beam, with Uniaxial, and Rosette Strain gauges
2. Wheatstone Bride and Strain Gauge Meter.



Materials and Equipment

1. Cantilever flexure frame
2. No. B101 (2024-T6 high-strength aluminum alloy beam); 1/8 x 1 x 12.5 in. (3x25x320 mm) or similar.
3. P-3500 strain indicator or equivalent (see Lab manual for details)
4. Micrometer
5. Calipers
6. Scale
7. Weights and hanger

Theory:

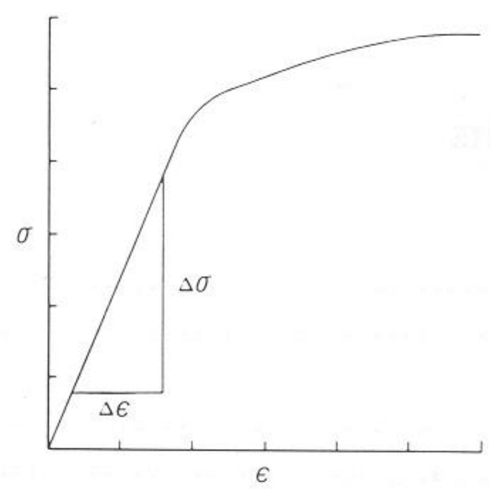
Refer to Mechanics of Material Laboratory manual for detail information.

Summary of Theory:

Principal Stresses:
These are the normal stresses acting on planes of zero shear stress. For a general state of stress there are three orthogonal principal stresses. The three principal directions for the principal stresses are orthogonal. The strains corresponding to principal stresses are called as principal strains. It is customary to order the principal stresses such that $\sigma_1 > \sigma_2 > \sigma_3$

Principal Planes:
Principal planes are the planes of zero shear stress. These planes are perpendicular to the principal directions i.e., directions along which the 3 principal stresses act.

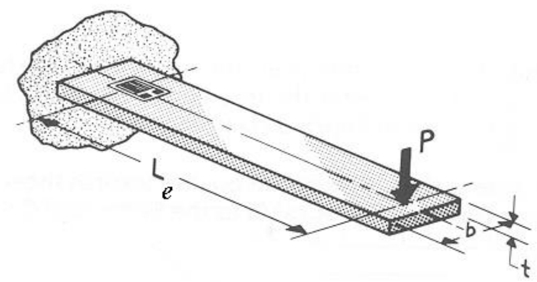
The modulus of elasticity, or Young's modulus, is a material constant indicative of the material's stiffness. It is obtained from the stress versus strain plot of a specimen subjected to a uniaxial stress state (tension, compression, or bending). Figure 1, for example, shows a typical "stress-strain" diagram for a metal under uniaxial stress. For materials such as aluminum, strain is an essentially linear function of the stress up to the point at which the material yields. Figure 1



The modulus of elasticity, E, is defined as the slope of the linear portion of the diagram.

$$E = \Delta\sigma/\Delta\varepsilon \quad (1)$$

Where σ is the stress measured in psi (N/m^2 or Pa).
In Equation above ε is the strain measured in in/in (m/m).
Thus, the elastic modulus is measured in units of psi (Pa).



A uniaxial stress state is obtained on the surface of a cantilever beam when it is loaded at its free end. The loading condition, illustrated in Figure 2, places the beam in a combined shear and bending state but the shear stresses are zero on the upper and lower surfaces. The bending tresses are directed along the longitudinal axis of the beam; they maximize on the upper surface and decrease linearly through the thickness. When the beam has a rectangular cross-section, the magnitude of the tensile stress on the upper surface is equal to that of the compressive stress on the lower surface.

(2) $$\sigma = MC/I$$

For cantilever beam $$\sigma = (6PL_e)/(bt^2) \quad (3)$$

Where b, and t are beam width and thickness and L_e is equivalent length of Beam, as shown above.

Preparation for the lab:

1. What is the maximum load that could be applied to an aluminum Beam with thickness of 5 mm and with of 24 mm and equivalent length of 20 cm? Use aluminum bars with average Yield Strength.
2. What will be the maximum deflection at the end tip?
3. Plot a graph, indicating Deflection and as function of load. Use this chart for application of Weights.
4. What is Hooke's Law?

Procedure

The surface strain at the section of interest will be measured by a strain gage bonded at that point. The load will be applied in increments, and the corresponding strains recorded. The stresses and strains will be plotted to produce a stress-strain diagram rom which the modulus of elasticity is determined. Information should be entered on the attached work sheet. The steps to be followed are:

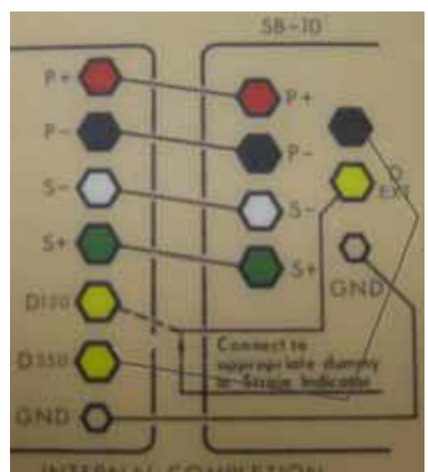
1. Measure and record the beam width (b), beam thickness (t), and effective length (L_e).
2. Record the gage factor, S_g, indicated on the beam.
3. Using Equation (3), determine the load, P, to be applied for a stress, σ, of 15,000 psi to result at the strain gage. This is the maximum load that can be safely applied to the beam without exceeding the yield stress, and is defined as P_{max} (a few pounds).

4. With the gaged end of the beam near the support, center the beam in the flexure frame and firmly clamp the beam in place.
5. Referring to Figure below (and Handout), connect the lead wires from the strain gage to the posts on the sides of the "flexor" frame. Referring to Figures connect the appropriate gage leads from the Flexor cable to the S-, P+, and D-120 binding posts of the P-3500 strain indicator. Note:

The strain gage employed in this experiment is used in a "Full-bridge" arrangement and Uniaxial Strains Only.

Connections:

1. The connections between strain indicator and balance unit are as the above photo



2. Strain gage #1 (on top of the beam), single wire goes to RED terminal at CH#9, two ground wires go to the WHITE & YELLOW terminals.
3. Strain gage #2 (on bottom of the beam), single wire goes to RED terminal at CH#10, two ground wires go to the WHITE & YELLOW terminals.

1. Press "**AMP ZERO** ±strain value to "0" for strain gage #2.
2. 2 Press "**GAGE FACTOR**", and set it to "value listed on Beam"
3. Place the "**WEIGHT HANGER**"
4. Press "**RUN**", switch to the **CHANNEL #10,** and use the "**BALANCE KNOB at CH#10**" to balance the strain value to "0" for strain gage #1.
5. The strain is shown in the strain gauge indicator panel.

   Apply the calibrated load in 10 steps, or increments. At each increment, record the indicated strain and corresponding load on the worksheet. Unload the beam in 10 decrements and again record the load and strain at each decrement.

Required CALCULATIONS:

1. Calculate the beam stress at the gage for the applied loads using the flexure formula.
2. Make a stress vs. strain graph by plotting the (stress, strain) points. Use both the increasing and decreasing load data.
3. From your graph determine the modulus of elasticity. Be certain to watch units.
4. From your text or another material handbook find the standard value for the modulus of elasticity of 2024-T6 aluminum. Calculate the percentage error in your experiment.
5. Find Principal Stresses and Strains from measured values.
6. Compare the measured values with Theoretical calculations.
7. Find Principal Stresses
8. Find Angel of Principal Stresses.
9. Compare the measured principal stresses to Theoretical One.
10. Plot the results. Discuss the observations.

Some Useful Formulas:

$$\upsilon = \left|\frac{\varepsilon_q}{\varepsilon_p}\right| = \_\_\_\_\_\_\_\_$$

$$\sigma_p = \frac{E}{(1-\upsilon^2)}(\varepsilon_p + \upsilon\varepsilon_q) = \_\_\_\_\_\_\_\_$$

$$\sigma_q = \frac{E}{(1-\upsilon^2)}(\varepsilon_q + \upsilon\varepsilon_p) = \_\_\_\_\_\_\_\_$$

DISCUSSION:

1. What are possible sources of error?
2. Were your errors within reasonable limits (< 10%)?
3. Were your increasing and decreasing graphs the same? Why not?

Possible Charts and Tables:

A. Observed measurements:

Load (Kg)	Experimental			Corrected Experimental		
	ε_1 (με)	ε_2 (με)	ε_3 (με)	ε_1' (με)	ε_2' (με)	ε_3' (με)
0.5						
1.0						
1.5						
2.0						

B. TABULATION OF LOADS, STRAINS, AND STRESSES:

LOAD (gm)	STRAIN (ε) μ/μ	STRESS (psi) (INCREASING LOAD)	STRAIN (με) (DECREASING LOAD)	STRESS (psi) (DECREASING LOAD)