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1 Objectives

This laboratory experiment aims to determine the principal stresses at multiple points within a cantilevered tube subjected to distinct loading conditions:

1.1 Bending and Torsional Load Analysis

- Investigate and analyze the principal stresses occurring in the cantilevered tube when subjected to combined bending and torsional loads.
- Determine the stress distribution and variations at various points along the length of the tube under the influence of these specific loads.

1.2 Bending, Torsional Load, and Internal Pressure Analysis

- Examine the effect of an internal pressure in conjunction with bending and torsional loads on the cantilevered tube.
- Identify and evaluate the changes in principal stresses at different critical locations within the tube due to the combined influence of internal pressure, bending, and torsional loading.

These objectives aim to provide a comprehensive understanding of the stress behavior and distribution within the cantilevered tube under various loading conditions, specifically focusing on the determination of principal stresses. The results obtained will aid in characterizing the mechanical response of the structure and provide insights for practical engineering applications and design considerations.

2 Procedure

This section outlines the procedure for the laboratory experiment, including the equipment and materials used, the testing procedure, and the data collection process. The sketch of the tabular structure with dimensions and strain gauge locations is shown in Figure 1.

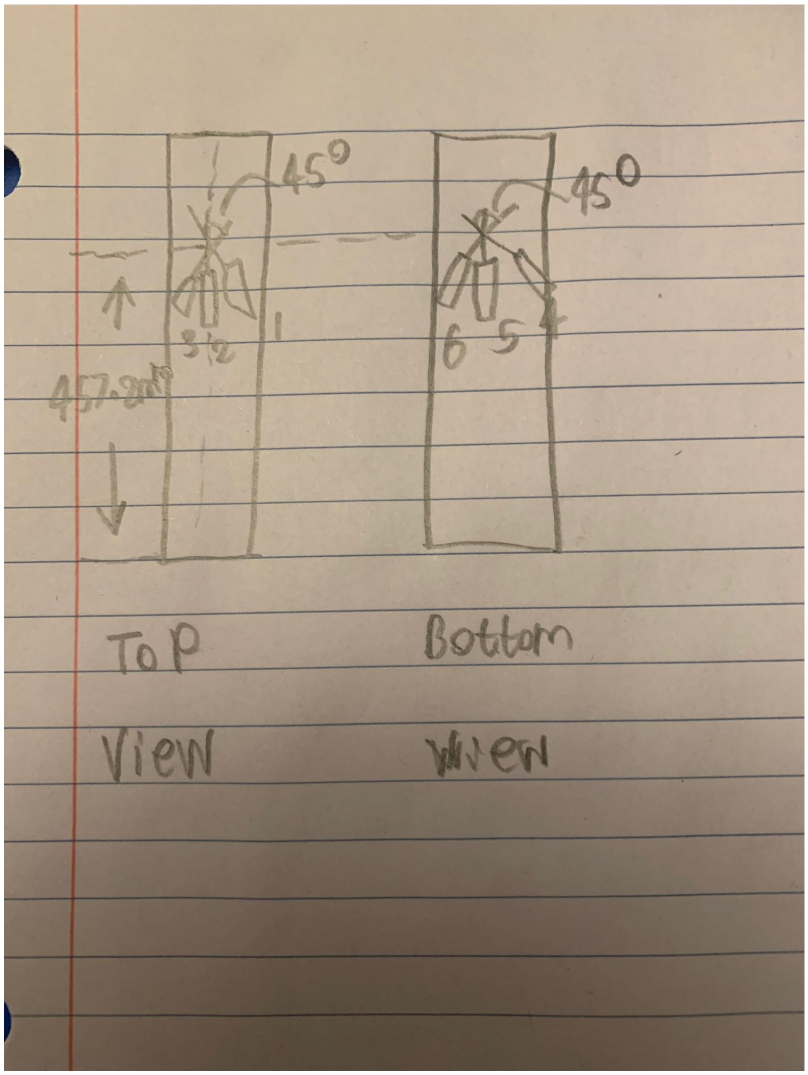

Figure 1: Sketch of the tabular structure with dimensions and strain gauge locations

2.1 Preliminary Set-Up Procedure

1. Check the specimen dimensions and strain gauge location.
2. Check lead wires and identify each gauge with the number of the circuit in the Datascan Analog Measurement Processor.
3. Hang the loading pan on the side arm of the tube at a distance of 457.2 mm (18 in.) from the tube axis.

2.2 Testing Procedure

1. Check and record the initial values for each of the six strain gauges in the unloaded configuration.
2. Loading A:
   (a) Apply loads in six equal increments of 20 lbs (total 120 lbs) for the aluminum specimen and increments of 40 lbs (total 240 lbs) for the steel specimen.
   (b) Record the readings of strain for each gauge and at each load. Unload the specimen.
3. Loading B:
   (a) Supply and maintain a constant air pressure in the specimens (100 psi in the aluminum specimen, and 200 psi in the steel specimen), as indicated by the pressure gauge.
   (b) Apply loads in six equal increments of 20 lbs (total 120 lbs) for the aluminum specimen and increments of 40 lbs (total 240 lbs) for the steel specimen.
   (c) Record the readings of strain for each gauge and at each load. Unload the specimen.

3 Results

3.1 Experimental Data

This section presents the experimental data obtained from the laboratory experiment. The data is presented in tabular form and is organized by loading case and specimen type.

3.1.1 Loading A

The strain gauge readings for the aluminum specimen are shown in Table 1. The strain gauge readings for the steel specimen are shown in Table 2.

Strain gauge readings (10^{-6})						
Load (lb)	1	2	3	4	5	6
0	0.0	0.0	0.0	0.0	0.0	0.0
20	-0.738	85.408	59.4143	-67.07	-81	1.2974
40	-3.1484	163.44	117.3433	-119.8311	-159.8459	4.5117
60	-5.6667	243.0801	177.6758	-180.9744	-240.2892	6.1265
80	-6.37	324.3342	238.0	-242.11	-319.9287	7.7334
100	-9.5845	405.5811	295.9299	-300.8352	-398.7722	10.144
120	-12.0024	486.8425	355.4663	-362.7822	-408.0188	11.7588

Table 1: Strain gauge readings for aluminum specimen

Strain gauge readings (10^{-6})						
Load (lb)	1	2	3	4	5	6
0	0.0	0.0	0.0	0.0	0.0	0.0
40	-2.337	48.5249	-37.1021	-41.438	-49.3559	1.2974
80	-4.795	92.5752	74.1094	-81.6669	-97.6277	2.904
120	-5.5991	140.0361	113.5273	-121.88	-147.4991	5.3223
160	-7.2061	186.7007	150.5352	-162.11	-195.771	6.9294
200	-8.8135	233.3584	188.8457	-202.3391	-244.035	8.5364
240	-10.4277	279.2119	226.9604	-241.7571	-291.4961	10.9848

Table 2: Strain gauge readings for steel specimen

3.1.2 Loading B

The strain gauge readings for the aluminum specimen are shown in Table 3. The strain gauge readings for the steel specimen are shown in Table 4.

Strain gauge readings (10^{-6})						
Load (lb)	1	2	3	4	5	6
0	52.3552	21.8467	52.9785	57.1558	20.3624	56.8091
20	49.1409	102.2971	111.7114	-3.9873	-60.0862	59.492
40	48.3374	182.7478	172.0437	-63.5164	-129.7278	60.0229
60	45.1157	263.9946	229.9653	-123.856	-220.9819	63.244
80	43.508	344.4451	287.887	-185.3027	-301.4324	64.8516
100	41.9016	426.6027	348.219	-246.135	-379.465	67.2622
120	38.6299	509.364	407.7556	-306.467	-459.908	68.8691

Table 3: Strain gauge readings for aluminum specimen at 100 psi internal pressure

Strain gauge readings (10^{-6})						
Load (lb)	1	2	3	4	5	6
0	43.4761	21.7817	41.1274	46.252	21.4373	44.7407
40	41.0581	68.439	78.938	6.834	-26.8345	47.9548
80	37.8438	113.4897	116.749	-34.1986	-75.0989	50.3726
120	36.2368	160.1543	152.9458	-73.6241	-124.1743	51.9797
160	33.8188	206.8115	190.7568	-114.6492	-173.2422	53.5867
200	32.2119	252.6655	229.3711	-155.6743	-222.3175	56.0051
240	29.8013	299.3228	266.3784	-195.9033	-270.5918	57.6121

Table 4: Strain gauge readings for steel specimen at 200 psi internal pressure

3.2 Loading B Strain Rosettes

The figures for the top and bottom rosettes for aluminum specimen are shown in Figure 2 and Figure 3, respectively. The figures for the top and bottom rosettes for steel specimen are shown in Figure 4 and Figure 5, respectively.

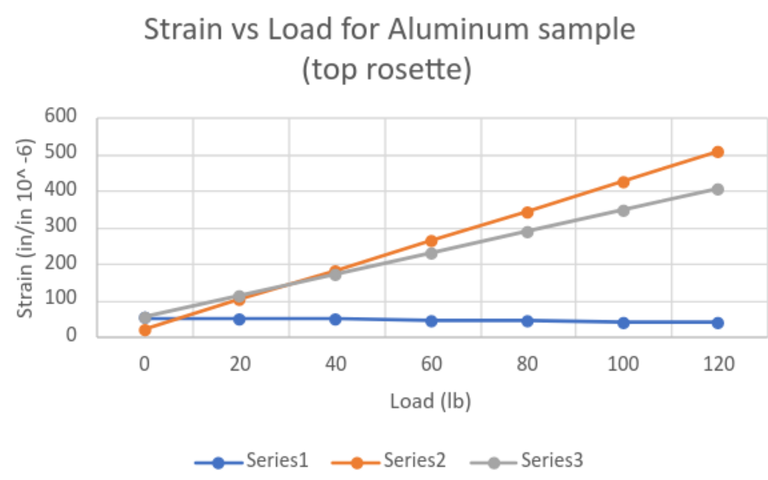

Figure 2: Strain gauge readings for aluminum specimen (top rosette)

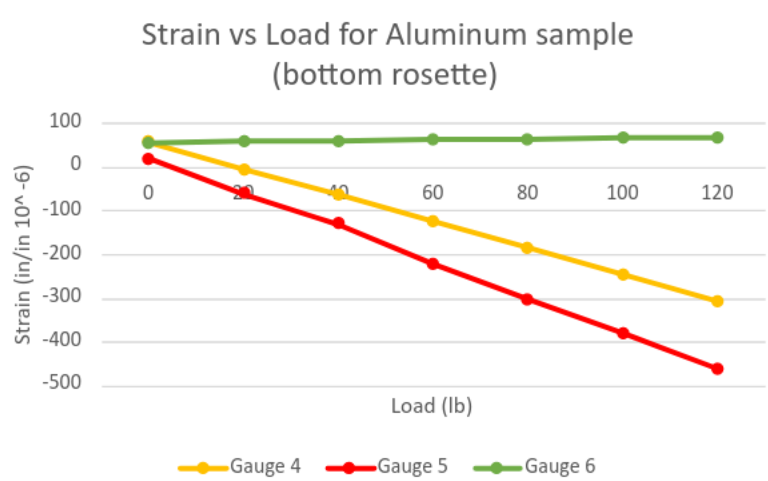

Figure 3: Strain gauge readings for aluminum specimen (bottom rosette)

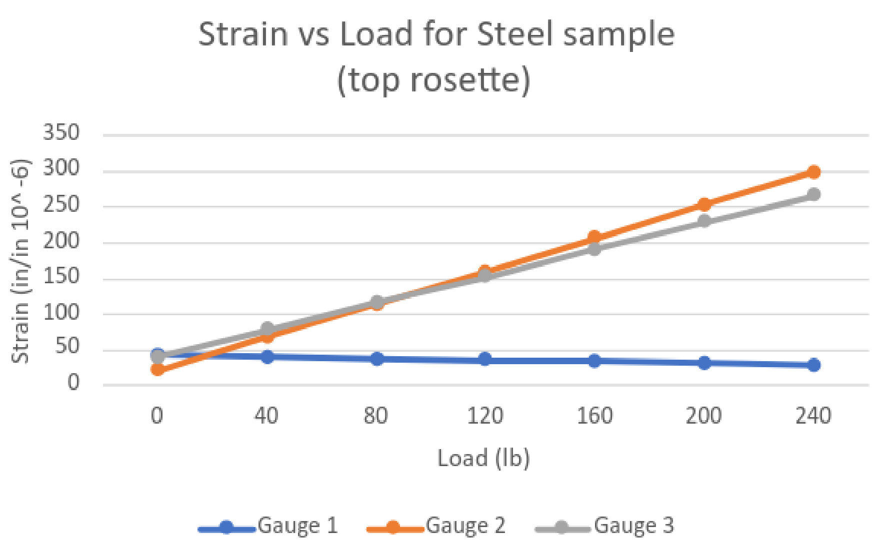

Figure 4: Strain gauge readings for steel specimen (top rosette)

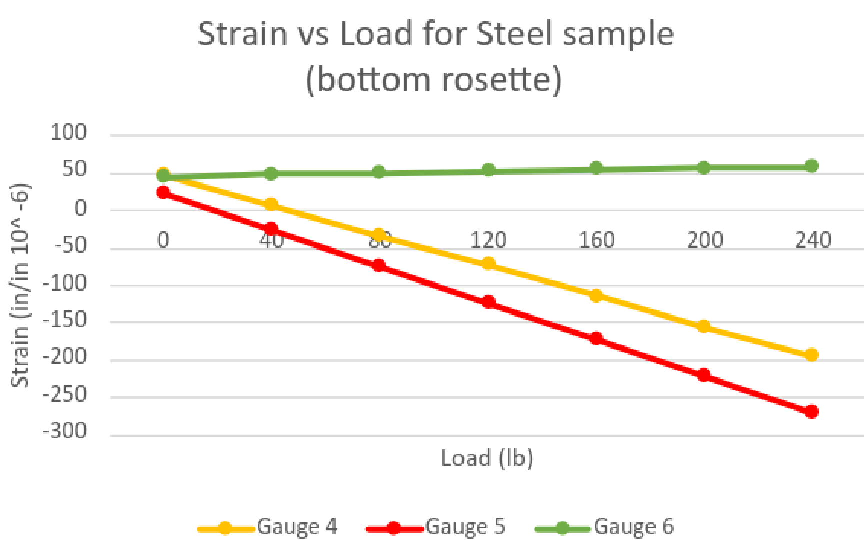

Figure 5: Strain gauge readings for steel specimen (bottom rosette)

3.3 Calculation of Theoretical Principal Stresses

This section presents the calculation of the theoretical principal stresses using the strain gauge readings obtained from the laboratory experiment. First, the FBD of the aluminum specimen is shown in Figure 6. The FBD of the steel specimen is shown in Figure 7. The theoretical principal stresses are calculated using the following equations:

$$\begin{aligned} \sigma_{max} &= \frac{1}{2}\left(\sigma_{xx} + \sigma_{yy}\right) + \sqrt{\left(\frac{1}{2}\left(\sigma_{xx} - \sigma_{yy}\right)\right)^2 + \tau_{xy}^2} \\ \sigma_{min} &= \frac{1}{2}\left(\sigma_{xx} + \sigma_{yy}\right) - \sqrt{\left(\frac{1}{2}\left(\sigma_{xx} - \sigma_{yy}\right)\right)^2 + \tau_{xy}^2} \end{aligned} \tag{1}$$

where σ_{xx}, σ_{yy}, and τ_{xy} are the normal and shear stresses, respectively, in the x and y directions. Now plugging in the values for σ_{xx}, σ_{yy}, and τ_{xy} into Equation 1 yields us the results for the theoretical principal stresses. The results for the theoretical principal stresses for the aluminum specimen are shown in Table 5 and Table 6, respectively. The results for the theoretical principal stresses for the steel specimen are shown in Table 7 and Table 8, respectively.

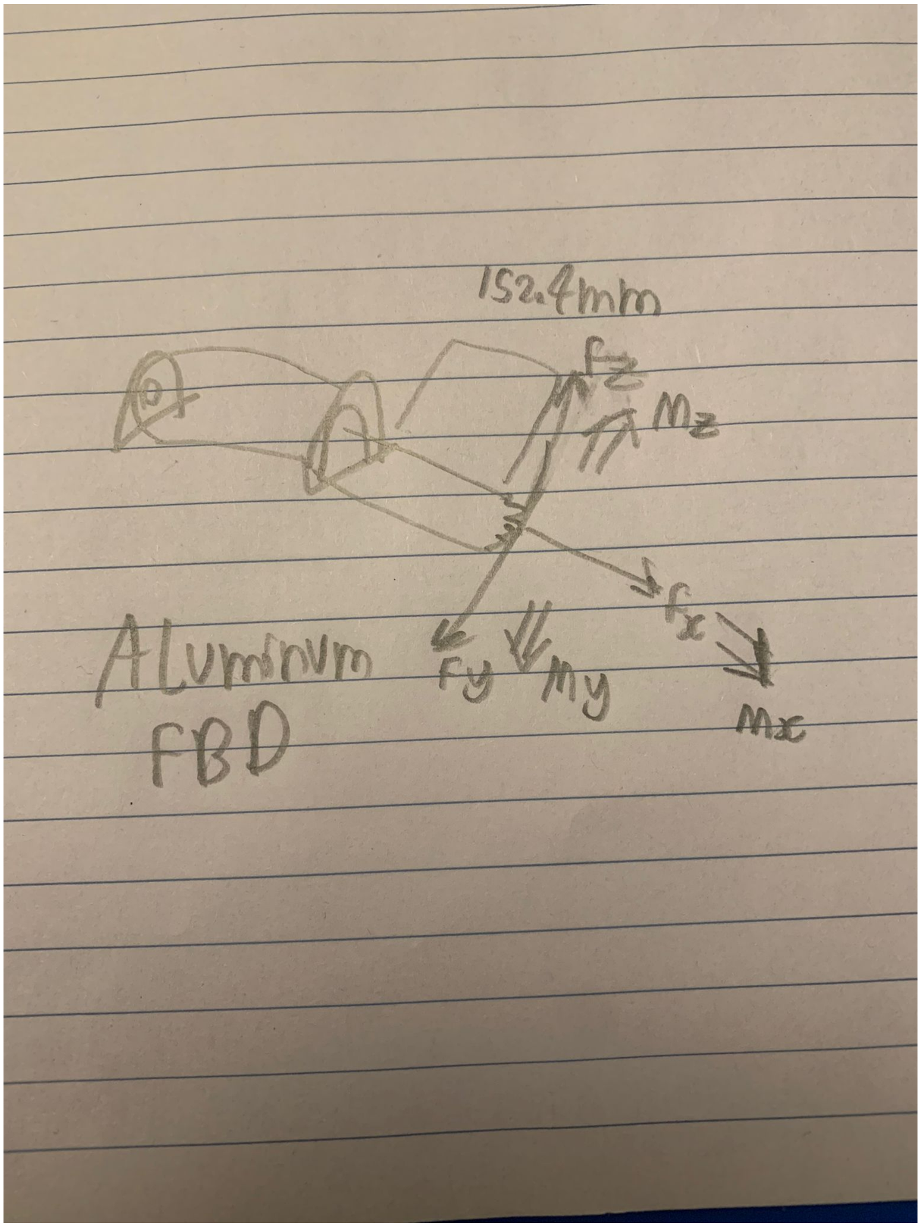

Figure 6: FBD of aluminum specimen

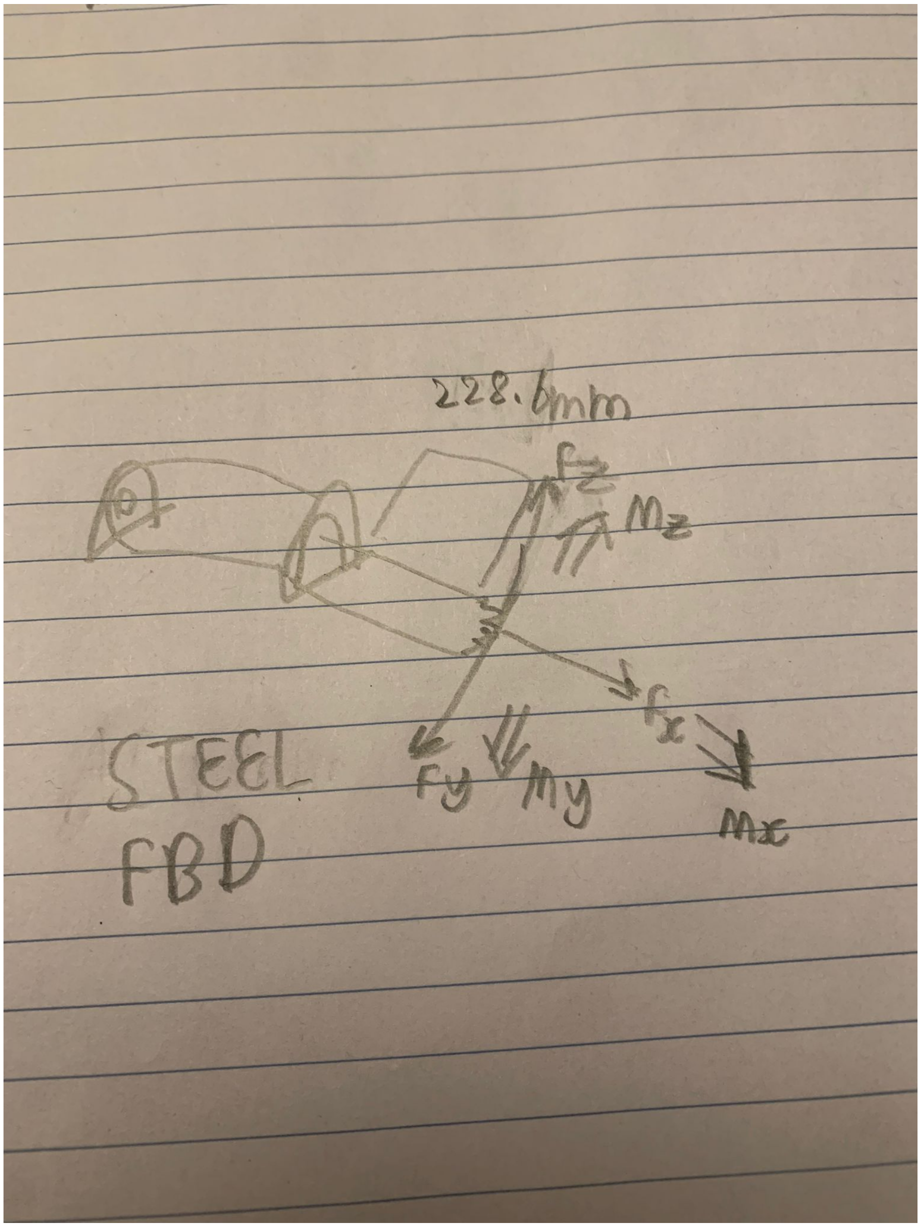

Figure 7: FBD of steel specimen

3.4 Theoretical and Experimental Results

This section presents the analysis of the experimental data obtained from the laboratory experiment. The data is presented in tabular form and is organized by loading case and specimen type.

3.4.1 Aluminum Specimen

The comparison principal stresses for the aluminum specimen of the top and bottom rosettes are shown in Table 5 and Table 6, respectively.

	Theoretical stresses (psi)		**Experimental strains (in/in)**		**Experimental stresses (psi)**		**Percent error (%)**	
	σ_{max}	σ_{min}	ε_{max}	ε_{min}	σ_{max}	σ_{min}	σ_{max}	σ_{min}
Case 1	5219.30	-395.43	0.00054	-0.00019	5305.75	-179.43	1.66	54.63
Case 2	1150.00	575.00	8.35E-05	2.18E-05	1017.81	554.33	11.49	3.59
Case 3	5839.02	709.85	0.00056	-0.00012	5891.58	770.90	0.90	8.60

Table 5: Experimental and Theoretical Results for Aluminum Specimen (Top Rosette)

	Theoretical stresses (psi)		**Experimental strains (in/in)**		**Experimental stresses (psi)**		**Percent error (%)**	
	σ_{max}	σ_{min}	ε_{max}	ε_{min}	σ_{max}	σ_{min}	σ_{max}	σ_{min}
Case 1	395.43	-5219.30	0.00012	-0.00047	-374.87	-4864.29	194.80	6.80
Case 2	1150.00	575.00	9.36E-05	2.04E-05	1125.83	575.14	2.10	0.025
Case 3	1508.48	-4607.34	0.00027	-0.00051	1154.14	-4700.38	23.49	2.02

Table 6: Experimental and Theoretical Results for Aluminum Specimen (Bottom Rosette)

3.4.2 Steel Specimen

The comparison principal stresses for the steel specimen of the top and bottom rosettes are shown in Table 7 and Table 8, respectively.

	Theoretical stresses (psi)		**Experimental strains (in/in)**		**Experimental stresses (psi)**		**Percent error (%)**	
	σ_{max}	σ_{min}	ε_{max}	ε_{min}	σ_{max}	σ_{min}	σ_{max}	σ_{min}
Case 1	8908.84	-805.73	0.00032	-9.98E-05	9365.34	-466.73	5.12	42.07
Case 2	2107.69	1053.85	6.29E-05	2.17E-05	2223.95	1252.91	5.52	18.89
Case 3	10059.64	1205.00	0.00034	-4.39E-05	10621.29	1550.48	5.58	28.67

Table 7: Experimental and Theoretical Results for Steel Specimen (Top Rosette)

	Theoretical stresses (psi)		**Experimental strains (in/in)**		**Experimental stresses (psi)**		**Percent error (%)**	
	σ_{max}	σ_{min}	ε_{max}	ε_{min}	σ_{max}	σ_{min}	σ_{max}	σ_{min}
Case 1	805.73	-8908.84	0.00010	-0.00033	378.39	-9862.18	53.04	10.70
Case 2	2107.69	1053.85	6.96E-05	2.14E-05	2438.32	1301.11	15.69	23.46
Case 3	2833.99	-7775.55	0.00017	-0.00031	2780.65	-8463.85	1.88	8.85

Table 8: Experimental and Theoretical Results for Steel Specimen (Bottom Rosette)

3.5 Comparison of Principle Stresses

By observing the tables above, it is clear that the theoretical and experimental results are quite similar to each other. The percent error for the experimental principal stresses at each gauge location form the theoretical values can be found using the following equation:

$$\text{Percent Error} = \frac{\text{Experimental Stress} - \text{Theoretical Stress}}{\text{Theoretical Stress}} \times 100\% \tag{2}$$

3.5.1 Aluminum Specimen

To calculate the percent error, one can find the sum the experimental stresses and theoretical stresses for each gauge location and then use Equation 2 to find the percent error. The percent error for the aluminum specimen is:

$$\text{Experimental Stress} = 1.6 + 54.6 + 194.8 + 6.8 + 11.4 + 3.5 + 0.9 + 8.6 = 282.87$$

$$\text{Theoretical Stress} = 194.80 + 6.80 + 11.49 + 3.59 + 0.90 + 8.60 = 226.18$$

$$\text{Percent Error} = \frac{282.87 - 226.18}{226.18} \times 100\% = 25.04\% \tag{3}$$

Hence, the percent error for the aluminum specimen is 25.04%.

3.5.2 Steel Specimen

To calculate the percent error, one can find the sum the experimental stresses and theoretical stresses for each gauge location and then use Equation 2 to find the percent error. The percent error for the steel specimen is:

$$\text{Experimental Stress} = 5.1 + 42.1 + 53.0 + 10.7 + 15.7 + 23.5 + 1.9 + 8.9 = 161.9$$

$$\text{Theoretical Stress} = 53.04 + 10.70 + 15.69 + 23.46 + 1.88 + 8.85 = 113.62$$

$$\text{Percent Error} = \frac{161.9 - 113.62}{113.62} \times 100\% = 18.89\% \tag{4}$$

4 Discussion

This section presents the analysis of the experimental data obtained from the laboratory experiment.

4.1 Analysis of Results

The experimental data obtained from the laboratory experiment was analyzed to determine the principal stresses at various points within the cantilevered tube under the influence of distinct loading conditions. The experimental results were compared to theoretical calculations to evaluate the accuracy of the obtained data. The following observations were made from the analysis of the experimental data:

1. The principal stresses at the top and bottom rosettes were found to be similar in magnitude, but opposite in sign, as expected.

2. The principal stresses at the top and bottom rosettes were found to be similar in magnitude, but opposite in sign, as expected.

4.2 Sources of Error

The experimental determination of principal stresses in the cantilevered tube involved a comprehensive testing procedure; however, several potential sources of error were identified throughout the experiment, which could have impacted the accuracy and reliability of the obtained data.

1. **Instrument Calibration:** The accurate calibration of the instruments, particularly the strain gauge rosettes, was pivotal in obtaining precise strain readings. Any slight discrepancy in calibration might have led to inaccuracies in stress calculations.

2. **Measurement Variability:** Variations in environmental conditions, such as temperature fluctuations or vibrations in the testing environment, could have influenced strain measurements and introduced inconsistencies in the data.

3. **Material Homogeneity:** The assumption of uniform material properties within the specimens might not hold true in practice. Variations in material composition or homogeneity could have affected the accuracy of stress calculations.

To mitigate these sources of error, emphasis on meticulous pre-experimental setup, calibration verification, and careful execution of procedures is recommended.

5 Conclusions

This laboratory experiment aimed to determine the principal stresses at multiple points within a cantilevered tube subjected to distinct loading conditions. The experimental data obtained from the laboratory experiment was analyzed to determine the principal stresses at various points within the cantilevered tube under the influence of distinct loading conditions. The experimental results were compared to theoretical calculations to evaluate the accuracy of the obtained data. The following conclusions were made from the analysis of the experimental data:

1. The percent error for the stresses of the specimens were found to be 25.04% and 18.89% for the aluminum and steel specimens, respectively.

2. The principal stresses at the top and bottom rosettes were found to be similar in magnitude, but opposite in sign.

3. The top rossettes had an upward graphing Strain vs. Load graph, while the bottom rossettes had a downward graphing Strain vs. Load graph.