ME 556 Lab #4

Data and Answers Sheet

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Part I: Predictions

The load cell (i.e., "proving ring") used in this lab is intended to measure loads ranging from 0 to 200 lbf. The strain gages used have a gage factor of 2.15. What is the *predicted* load cell output (in mV/V)? (Attach calculation sheets to support your answer):

Predicted Load Cell Output = 1.95 mV/V

Part II: Measurements (complete the following tables by transferring the data requested from the Excel files created during the lab)

Loading ⟶

Excitation Voltage (V)	Initial Output Offset (mV)	Output Voltage at 40 lbf (mV)	Output Voltage at 80 lbf (mV)	Output Voltage at 120 lbf (mV)	Output Voltage at 160 lbf (mV)	Output Voltage at 200 lbf (mV)
0.5	0.031	0.214	0.397	0.61	0.733	0.977
2.0	-0.61	0.671	1.373	2.075	2.777	3.479
10.0	0	3.479	7.05	10.53	14.04	17.519

⟵ Unloading

Excitation Voltage (V)	Final Output Offset (mV)	Output Voltage at 40 lbf (mV)	Output Voltage at 80 lbf (mV)	Output Voltage at 120 lbf (mV)	Output Voltage at 160 lbf (mV)
0.5	0.0	0.183	0.366	0.58	0.763
2.0	-0.061	0.671	1.343	2.045	2.777
10.0	0	3.51	7.02	10.53	14.04

Part III: Data Reduction

Based on the measurements obtained in Part II, what is the experimentally-determined load cell output (in mV/V)? (Attach calculation sheets to support your answer):

Measured Load Cell Output = 1.804 mV/V

Part I: Predicted Load Cell Output

Gages 1 through 4 measure "tangential" (or "hoop") strains induced normal to the horizontal axis. Also, since the gages are mounted on free surfaces, they are subjected to a uniaxial state of stress and Hooke's Law becomes: $\varepsilon = \sigma / E$. From curved beam theory it is known that the tangential stresses induced along the horizontal axis are given by:

$$\sigma = \frac{P}{2A} + \frac{M_o(R-r)}{Ar(\bar{r}-R)}$$

where:

$$M_o = P\bar{r}\left(\frac{1}{2} - \frac{1}{\pi}\right)$$

A = cross-sectional area = (depth) ($r_2 - r_1$)

$\bar{r} = (r_2 + r_1)/2$

$R = \dfrac{(r_2 - r_1)}{\ln \dfrac{r_2}{r_1}}$ (for rectangular cross-sections)

Young’s modulus is specified as E = 10.6Msi, and numerical values of the needed dimensions are:

depth = 0.50 in
r_2 = 1.50 in
r_1 = 1.25 in

Combining the above and substituting all known quantities, the strain predicted at gage sites 1 and 4 is:

$$\varepsilon_{1,4} = (-0.3887x10^{-5})P \quad (in/in)$$

Similarly, the strain predicted at gage sites 2 and 3 is:

$$\varepsilon_{2,3} = (0.5193x10^{-5})P \quad (in/in)$$

Referring to the lab handout, note that:

- the Wheatstone bridge is wired such that the gage responses are additive
- the resistance ratio is unity ($r = 1$), since all four gages have the same resistance
- the gage factor is the same for all gages, and hence for each gage (ignoring transverse sensitivity effects): $\Delta R / R = S_g \varepsilon = 2.15\varepsilon$

The output for the Wheatstone bridge is therefore predicted to be:

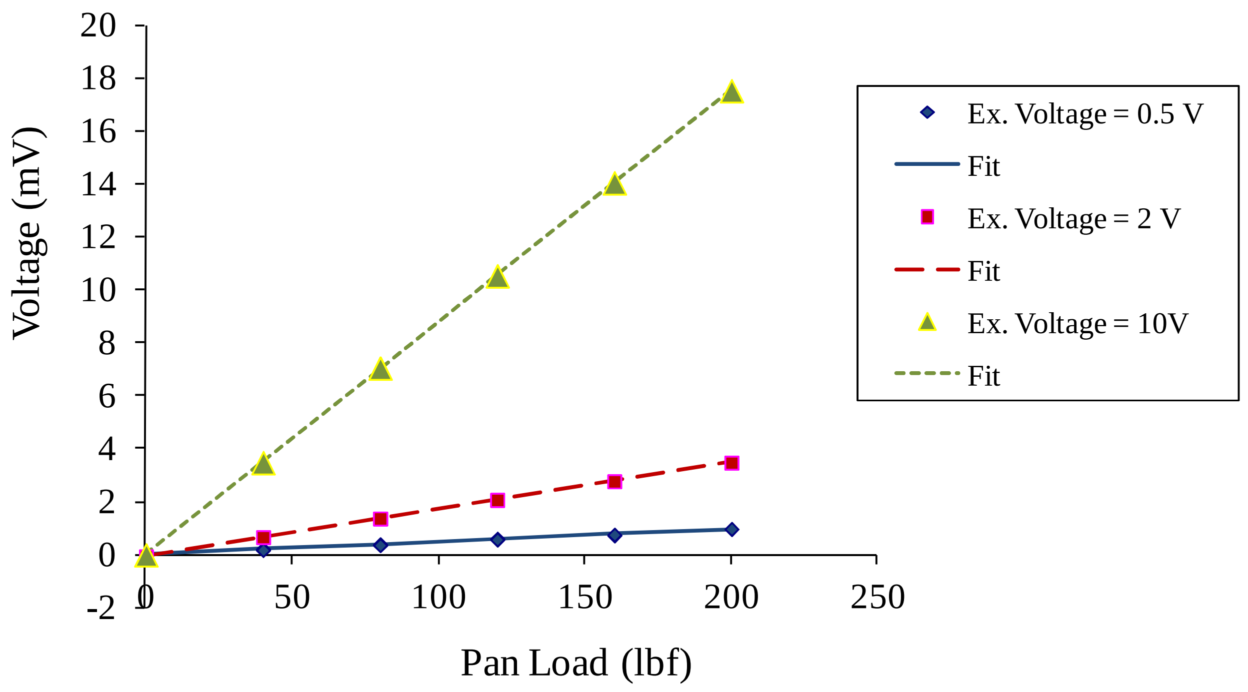
$$\frac{V_o}{V_s} = \frac{P}{4}\left[2(2.15)(0.5193x10^{-5}) + (2)(2.15)(0.3887x10^{-5})\right]$$

The load cell is intended to measure loads as high as 200 lbf, and the load cell "output" is defined at this maximum load level:

$$\text{PREDICTED OUTPUT} = \frac{200(2)(2.15)}{4}\left[(0.5193x10^{-5}) + (0.3887x10^{-5})\right] = 1.95 \ \ mV/V$$

Part III: Measured Load Cell Output

(1) A plot of (Output Voltage) vs (Load) for the three excitation levels considered is shown below. A curve fit (including offset) for each data set is included in the legend.



(2) A plot of output voltage normalized by the excitation voltage is shown on the following page. The plot was generated by:

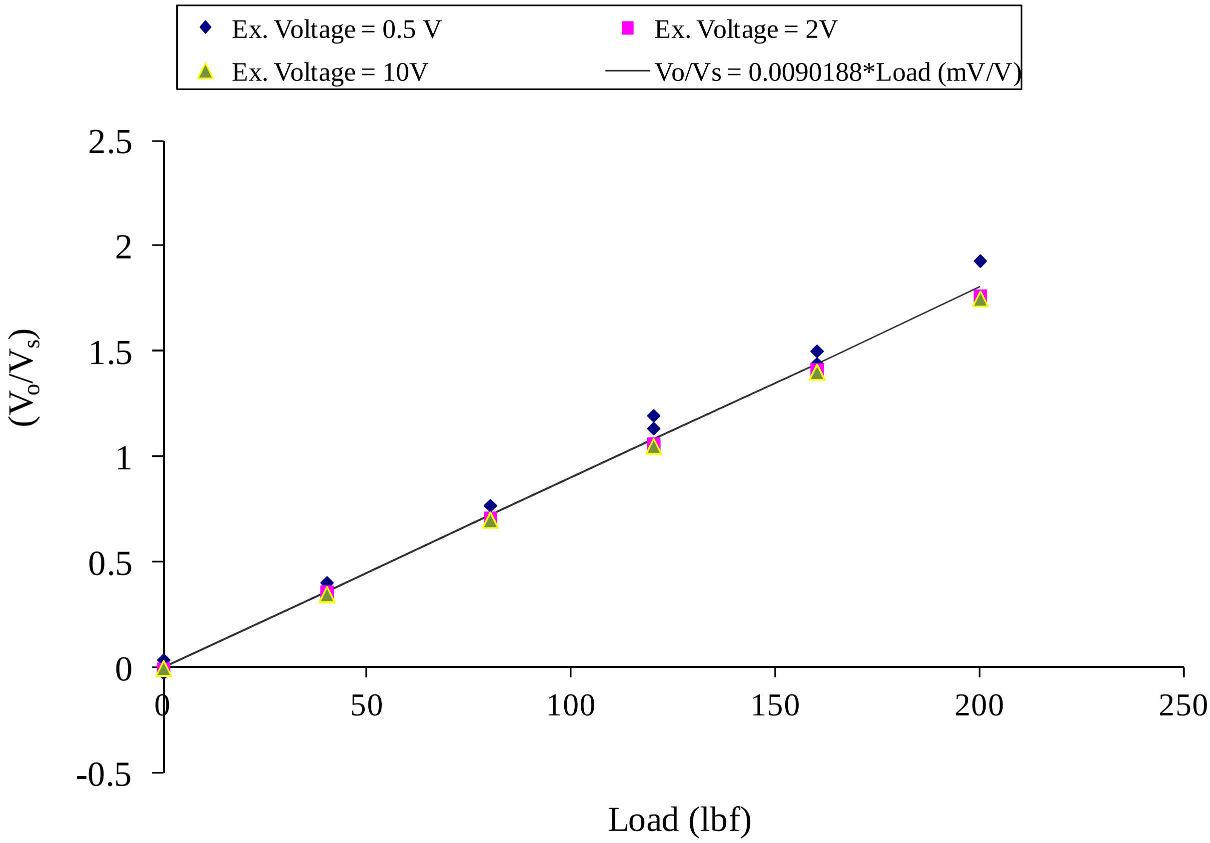
(a) subtracting the initial offset voltage corresponding to the excitation voltage (the offset was calculated using linear regression in step 1),
(b) dividing by the excitation voltage, and
(c) fitting a straight line to the entire normalized data set using linear regression.

As indicated in the plot, linear regression of the normalized data gave:

$$\frac{V_o}{V_s} = 0.0090188P \ \text{(mV/V)}$$

The measured load cell output is evaluated at P = 200 lbf, and is therefore found to be

$$\frac{V_o}{V_s} = (0.0090188)(200) = 1.804\, mV/V \text{ (reasonably close to predicted value)}$$



Ex. Voltage = 0.5 V
Ex. Voltage = 2V
Ex. Voltage = 10V
Vo/Vs = 0.0090188*Load (mV/V)
2.5
2
1.5
1
0.5
0
-0.5
(Vo/Vs)
0
50
100
150
200
250
Load (lbf)