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***Lab #3: Measurement of Length and Displacement***

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| **Course Number and Name:**  **ASE 269K Measurements and Instrumentation** | |
| **Semester and Year:**  **Fall 2013** | |
| **Name of Reporter:**  Zachary Tschirhart | **EID of Reporter:**  zst75 |
| **Unique Number and Meeting Time:**  13580 Monday 1-3pm | **Name of Lab Instructor**  **Zheng Wang** |
| **Title of Experiment:**  Measurement of Length and Displacement | |
| **Date of Experiment Performed:**  September 23, 2013 | **Instructor Comments:** |
| **Date of Report Submitted:**  September 30, 2013 |
| **Names of Group Members:**  Dayle Chang |
| **Grade:** |

**ABSTRACT**

This lab was intended to familiarize students with measuring length and displacement using a dial gage and DCDT Transducer. The students calibrated the transducers by measuring standard gage blocks with a micrometer then with the DCDT and the dial gage. Using these calibrated transducers, the students then measured the deflection of a cantilever beam in bending, showing that the dial gage had an effect on the measurement of the beam due to nonlinear effect near the end of the beam. Overall, the results were very close to the theoretical values, besides a constant offset. The error propagation was also calculated which encompassed all of the deflection values.

**OBJECTIVE AND INTRODUCTION**

The objective of this lab is to introduce students to measuring length and displacement using a dial gage and DCDT. Students should learn the difference between the two measuring devices. The individual experiments contain length measurements, calibration of both the dial gage and DCDT, and deflection measurements. Equipment consists of Steel Ruler, Gage Blocks, Micrometer, Dial Indicator, Load Frame Beam, DCDT Displacement Transducer, DC Power Supply, Multimeter, Gage Holder and Accessories, and Weights.

**THEORY AND EXPERIMENTAL METHODS**

Uncertainty calculation:

(1)

Where P is the accuracy range of the device, as a percentage, U is the value read from the device, and X is the number of digits of accuracy, and Y is the resolution of the measurement.

Deflection equation for a cantilever beam:

(2)

Where P is the force applied, x is the position where the deflection is being measured, E is Young’s Modulus, I is the moment of inertia, and L is the length of the beam.

Moment of Inertia for a cantilever beam:

(3)

Where b is the beam width and h is the thickness of the beam.

Error propagation for a cantilever beam:

(4)

Where Δ is the uncertainty in each of the values, ν is the beam deflection, L is the beam length, b is the beam width, h is the beam thickness, and E is Young’s Modulus. P is a given value, so it does not need to be taken into consideration.

**RESULTS AND DISCUSSION**

**Section 1: Simple Length Measurements**

**1.1**

Question – “Record the measured thickness of each of the four blocks using the micrometer.”

|  |  |  |
| --- | --- | --- |
| Block Number | Standard Reading | Micrometer Reading |
| 1 | 0.0625 in. | 0.0620 in. |
| 2 | 0.1250 in. | 0.1250 in. |
| 3 | 0.2500 in. | 0.2500 in. |
| 4 | 0.5000 in. | 0.5000 in. |

Table 1: Recorded gage block thicknesses using a Micrometer

**1.2**

Question - “Obtain the dimensions of the beam.”

Width = 1.0000 in.

Thickness = 0.1260 in.

Length = 14.25 in.

**Section 2: Calibration of a Dial Indicator and a DCDT**

**2.2**

Question – “Measure the gage blocks with the dial gage.”

|  |  |  |
| --- | --- | --- |
| Gage Blocks (in.) | Dial Indicator Reading (in.) | Dial Indicator Reading (in.) |
| 0.0000 | 0.110 | 0.112 |
| 0.0625 | 0.173 | 0.175 |
| 0.1250 | 0.235 | 0.237 |
| 0.1875 | 0.298 | 0.300 |
| 0.2500 | 0.361 | 0.362 |
| 0.3750 | 0.487 | 0.489 |
| 0.5000 | 0.612 | 0.612 |
| 0.6250 | 0.737 | 0.737 |
| 0.7500 | 0.862 | 0.862 |

Table 2: Recorded measurements of the gage blocks using the Dial Indicator

Homework Question – “Plot the indicator readings vs the gage block thickness”

Table 1: Gage block thickness versus the dial indicator reading

The plot shows a small discrepancy from the two measured paths in the range of 0 to 0.375 in. gage block size.

Question 1 – “What is the ‘resolution’ of the dial gage?”

The resolution of the dial gage is 0.001.

Question 2 – “Does the dial gage exhibit any hysteresis?”

No, but the data was slightly different from when we measured while increasing gage size to when we decreased gage size. The graph did not make a true loop, so this may have just been a skewed because the measuring apparatus was moved in the process of measuring.

Question 3 – “According to your measurements, what is the ‘nonlinearity’ of the dial gage?”

There isn’t really nonlinearity with any single measurement path, but there was a diversion in the data that was collected, which may be interpreted as nonlinearity in a very loose sense. This happened around 0.489 inches according to the dial indicator reading while measuring the blocks in descending order.

**2.4**

Question – “Measure the gage blocks using the DCDT instrument.”

|  |  |  |  |
| --- | --- | --- | --- |
| Gage Blocks, inches | DCDT, 5V | DCDT, 6V | DCDT, 7V |
| 0.000 | 0.0080 ± 0.0100 V | -0.0011 ± 0.0100 V | 0.0013 ± 0.0100 V |
| 0.0625 | 0.2796 ± 0.0101 V | 0.3147 ± 0.0101 V |  |
| 0.1250 | 0.5522 ± 0.0101 V | 0.6311 ± 0.0102 V |  |
| 0.1875 | 0.8238 ± 0.0102 V | 0.9447 ± 0.0102 V |  |
| 0.2500 | 1.0881 ± 0.0103 V | 1.2621 ± 0.0103 V | 1.4439 ± 0.0104 V |
| 0.3750 | 1.6321 ± 0.0104 V | 1.8973 ± 0.0105 V |  |
| 0.5000 | 2.1751 ± 0.0105 V | 2.5320 ± 0.0106 V | 2.9022 ± 0.0107 V |
| 0.6250 | 2.7114 ± 0.0107 V | 3.1736 ± 0.0108 V |  |
| 0.7500 | 3.2536 ± 0.0108 V | 3.7963 ± 0.0109 V | 4.3592 ± 0.0111 V |
| 0.8750 | 3.7894 ± 0.0109 V | 4.4380 ± 0.0111 V |  |
| 1.0000 | 4.3179 ± 0.0111 V | 5.076 ± 0.011 V | 5.817 ± 0.011 V |
| 1.2500 | 5.053 ± 0.011 V | 6.036 ± 0.011 V |  |
| 1.5000 | 5.239 ± 0.011 V | 6.498 ± 0.011 V |  |

Table 3: Gage measurements taken from the DCDT instrument including Multimeter errors.

Figure 2: Gage Size versus DCDT Output voltage with calibration factor trendlines

The Calibration factors are:

5V: 4.333 V/in. (Trendline: y = 4.333x)

6V: 5.070 V/in. (Trendline: y = 5.070x)

7V: 5.813 V/in. (Trendline: y = 5.813x)

Question 1 – “The specifications give the nonlinearity of the DCDT as ± 0.5% of the total stroke. What does that mean? ...”

This means that the measurements ± 0.5% of the total stroke are in the nonlinear range; anything within this percentage of the total stroke should be linear. Looking at Figure 2, the measurements of the 5V and 6V DCDT values outside of the specified stroke range (± 1.00 in.) are no longer linear.

Question 2 – “What do the term ‘high resolution’ as used in the specifications for the DCDT, mean? …”

There was no documentation with the device in the lab, but according to similar lab manuals found online, the DCDT can theoretically have infinite resolution as long as the measurement apparatus has the same resolution. This means that high resolution is the detection of small changes in thickness to certain accuracy. Since the Multimeter was used, we had a finite resolution. Our measurements do support this claim, since the use of the Multimeter was the limiting factor for our resolution.

Question 3 – “What is the linear range of the DCDT and what causes the nonlinearity?

The linear range of the DCDT is between 0 and 1 inch. The cause of this nonlinearity is due to the hysteresis effect caused by variances in the voltage or current from the DC power supply or the heating up of the components inside the DCDT.

**Section 3: Measurement of the Deflection Curve of a Cantilever Beam**

\*\***Note**: We did not have the proper lab equipment at our lab station, so the data below was collected by another group.

**3.3**

Question – Record the output of the DCDT in a table.

|  |  |  |
| --- | --- | --- |
| Mark | Initial DCDT Measurement (Volts) | Loaded DCDT Measurement (Volts) |
| 1 | 0.0764 ± 0.0100 V | -1.9051 ± 0.0105 V |
| 2 | 0.0720 ± 0.0100 V | -1.6721 ± 0.0104 V |
| 3 | 0.0590 ± 0.0100 V | -1.4050 ± 0.0104 V |
| 4 | 0.0520 ± 0.0100 V | -1.2150 ± 0.0103 V |
| 5 | -0.0027 ± 0.0100 V | -1.0460 ± 0.0103 V |
| 6 | -0.0130 ± 0.0100 V | -0.8612 ± 0.0102 V |
| 7 | -0.0379 ± 0.0100 V | -0.6901 ± 0.0102 V |
| 8 | -0.0482 ± 0.0100 V | -0.5248 ± 0.0101 V |
| 9 | -0.0787 ± 0.0100 V | -0.4160 ± 0.0101 V |
| 10 | -0.1029 ± 0.0100 V | -0.3217 ± 0.0101 V |
| 11 | -0.1371 ± 0.0100 V | -0.2587 ± 0.0101 V |
| 12 | -0.1577 ± 0.0100 V | -0.2069 ± 0.0101 V |

Figure 3: Measured voltages using the DCDT of the beam deflection

Using the calibration function for 6V, the deflection in inches is shown in the table below. Unfortunately, there was no second measurement taken for these values, so no variance or mean can be found. Also, it seems like the measurements were not really taken in the same range as the calibration record, but since the nonlinearity is within ± 1.00 inches, then this should still work. The only variance that could be calculated is the variance from using the Multimeter:

|  |  |  |  |
| --- | --- | --- | --- |
| Mark | Initial DCDT Measurement | Loaded DCDT Measurement | Total Deflection |
| 1 | 0.0151 ± 0.0020 in. | -0.3758 ± 0.0021 in. | 0.3908 ± 0.0041 in. |
| 2 | 0.0142 ± 0.0020 in. | -0.3298 ± 0.0021 in. | 0.3440 ± 0.0041 in. |
| 3 | 0.0116 ± 0.0020 in. | -0.2771 ± 0.0020 in. | 0.2888 ± 0.0040 in. |
| 4 | 0.0103 ± 0.0020 in. | -0.2396 ± 0.0020 in. | 0.2499 ± 0.0040 in. |
| 5 | -0.0005 ± 0.0020 in. | -0.2063 ± 0.0020 in. | 0.2058 ± 0.0040 in. |
| 6 | -0.0026 ± 0.0020 in. | -0.1699 ± 0.0020 in. | 0.1673 ± 0.0040 in. |
| 7 | -0.0075 ± 0.0020 in. | -0.1361 ± 0.0020 in. | 0.1286 ± 0.0040 in. |
| 8 | -0.0095 ± 0.0020 in. | -0.1035 ± 0.0020 in. | 0.0940 ± 0.0040 in. |
| 9 | -0.0155 ± 0.0020 in. | -0.0821 ± 0.0020 in. | 0.0665 ± 0.0040 in. |
| 10 | -0.0203 ± 0.0020 in. | -0.0635 ± 0.0020 in. | 0.0432 ± 0.0040 in. |
| 11 | -0.0270 ± 0.0020 in. | -0.0510 ± 0.0020 in. | 0.0240 ± 0.0040 in. |
| 12 | -0.0311 ± 0.0020 in. | -0.0408 ± 0.0020 in. | 0.0097 ± 0.0040 in. |

Table 4: Calculated deflections using the calibration equation.

**3.5**

Question – Use the dial indicator to measure the deflection in the beam.

|  |  |  |  |
| --- | --- | --- | --- |
| Mark | Initial Dial Gage Measurement | Loaded Dial Gage Measurement | Total Deflection |
| 1 | 0.530 in. | 0.278 in. | 0.352 in. |
| 2 | 0.555 in. | 0.331 in. | 0.324 in. |
| 3 | 0.570 in. | 0.385 in. | 0.285 in. |
| 4 | 0.583 in. | 0.440 in. | 0.243 in. |
| 5 | 0.596 in. | 0.491 in. | 0.205 in. |
| 6 | 0.603 in. | 0.438 in. | 0.165 in. |
| 7 | 0.608 in. | 0.577 in. | 0.131 in. |
| 8 | 0.610 in. | 0.514 in. | 0.096 in. |
| 9 | 0.613 in. | 0.546 in. | 0.067 in. |
| 10 | 0.610 in. | 0.566 in. | 0.044 in. |
| 11 | 0.601 in. | 0.579 in. | 0.022 in. |
| 12 | 0.601 in. | 0.592 in. | 0.009 in. |

Table 5: Recorded deflections using the dial gage.

Homework Question – “Plot the theoretical expression of the deflection curve along with the deflections measured using the DCDT and dial gage”

Using equation 2 and 3 to find the theoretical values for each of the gage marks and using deflection values from tables 4 and 5.

Figure 3: Measured and theoretical deflections versus the distance from the base of the cantilever beam.

Question 1 – “Estimate the uncertainty in the calculated tip deflection x = L due to uncertainties…”

Using equation 4, this was estimated to be 12.24% or ± 0.0303 inches if using the theoretical values as a reference.

Question 2 – “Should the DCDT and the dial gage give the same results in the beam deflection measurement?”

No, there is a force applied by the dial gage, which is seen clearly at the end of the beam in figure 3. This force is also not constant throughout each measurement of the beam, since the gage dial has a spring and force exerted is a function of the axial deflection of the gage and since the tip of the cantilever beam is more sensitive to smaller forces.

Question 3 – “Why was it desirable to preload the dial gage before setting the zero point?”

Preloading the dial gage before setting the zero point was used for several reasons. First, The beam is deflecting in a downward motion, so the dial needed to have axial movement in the downward direction. Second, the dial gage is more accurate when preloading, so there is not as much variance from vibrations and other movement. Third, the dial was used, and in a sense calibrated, for use under a preload condition in the previous section.

Question 4 – “Does the constant weight of the core of the DCDT cause any error in the beam deflection measurement?”

This does give a constant skew of measurements, but not as much as the dial gage. Since the constant weight is not a function of axial movement.

**CONCLUSIONS**

In conclusion, the lab was used to get students comfortable in measuring the length and displacement using a dial gage and DCDT Transducer. The students ended up calibrating the transducers and getting results very close to the theoretical values. During this procedure, the students also learned where the linear ranges of the instruments were. In particular, the cantilever beam deflections were predicted well and were within the measurement error range of 12.24%. Although, the beam measurement experienced nonlinearity with the dial gage near the end, which is caused by the apparatus applying force to the beam as well. Overall, the results were close to the theoretical values with relatively small errors, mostly constant from the measurement of the beam.

**BIBLIOGRAPHY**

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