MAE 3181 Materials and Structures Laboratory

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Laboratory Report #1

LVDT-Based Displacement Measurement Guidance

Submitted to

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by

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Summary

This experiment's objective is to generate a calibration curve for a Linear Variable Differential Transformer (LVDT) non-linear based measurement system. This calibration curve will allow for a more precise displacement measurement system. The voltage values were taken sequentially in increments of 1 mm going from zero millimeters to 20 millimeters then back down from twenty millimeters to zero millimeters. The average of the voltage value at a given increment was used to generate the calibration curve to mitigate the small hysteresis error that was present. The result of this experiment was a calibration curve that along with the associated equation of best curve fit can be used to measure displacement at a precise level.

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List of Symbols

Roman Symbols:

H Hysteresis
V Voltage

Subscripts:

u Up-pass voltage value at a given displacement increment
d Down-pass voltage value at a given displacement interval
avg Average

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1. Objectives of the Laboratory Experiments

a.

The objective of this LVDT experiment is to generate a calibration curve for the LVDT based displacement measurement system. This allows for a more precise measurement of length.

2. Experimental Setup

b.

The experiment setup consists of a micrometer thimble that is calibrated in millimeters, in which one full rotation corresponds to one-millimeter displacement. This micrometer thimble is connected to a translation block such that when the micrometer thimble is moved the translation block is moved in a one to one ratio. The translation block is in contact with one end of a connecting rod. The connecting rod is in contact with the translation block on one end and a metal core on the other end. The connecting rod is hinged at a point in the middle and the end that is connected to the metal core is curved as to make the system non-linear. The metal core moves in and out of the LVDT. The LVDT is connected to a rectifier which is in turn connected to a multimeter. The multimeter is a six-and-a-half-digit multimeter.

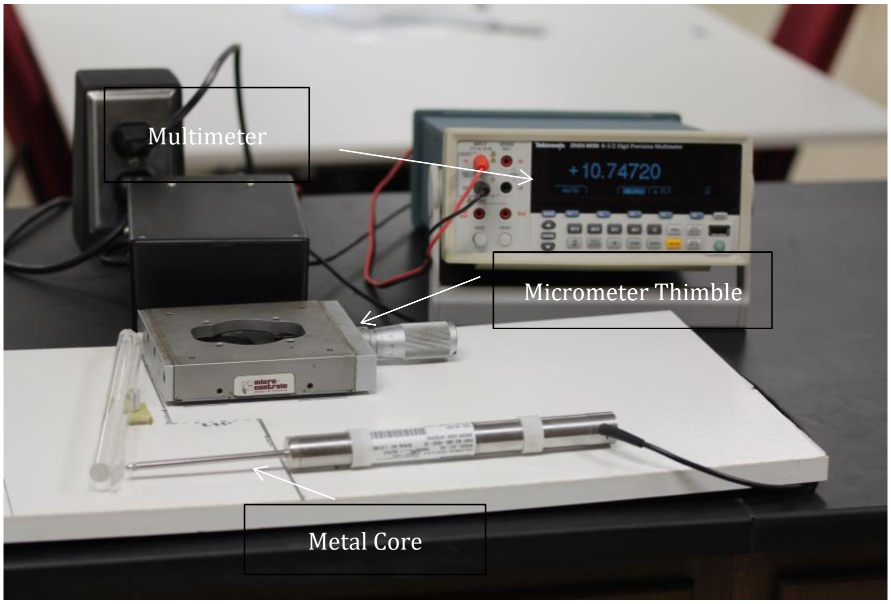

Figure 1. Experiment setup.

As seen in Fig. 1 the metal core surface and the translation block surface that are in contact with the connecting rod are parallel to each other.

$$V_{avg} = \frac{(V_u+V_d}{2} \tag{1}$$

$$H= |V_u - V_d| \tag{2}$$

3. Experimental Procedure and Results

c.

Start with the micrometer thimble at zero millimeters and note down the voltage displayed on the multimeter. Turn the micrometer thimble a full rotation to one millimeter then note down the voltage displayed on the micrometer. Repeat this process up to twenty millimeters with one-millimeter increments noting down the voltage displayed at each increment. Once twenty millimeters is reached record the voltage displayed for a second time then in increments of one full rotation of the micrometer thimble (one-millimeter) come back down to zero millimeters on the micrometer thimble recording the voltage reading at every increment. The raw data should be in the form of a six-and-a-half-digit voltage reading that corresponds to a displacement reading from the micrometer thimble. The raw data collected in this experiment can be found in the appendix. To ensure that no human error is introduced into the voltage readings take your hand completely off the micrometer thimble.

4. Data Analysis, Interpretation, and Discussion

The raw data was input by hand into Microsoft Excel in which all relevant data analysis took place. I believe that no error was introduced into the data during this process.

d.

The largest value of hysteresis observed in my data set was $5.30\text{x}10^{-3}$ V. This hysteresis value was found at 7 mm of displacement. I found this maximum hysteresis value by using Eq. 2. This maximum hysteresis value being less than a percent of the recorded voltage values signifies that the system suffers from minimum hysteresis error.

e.

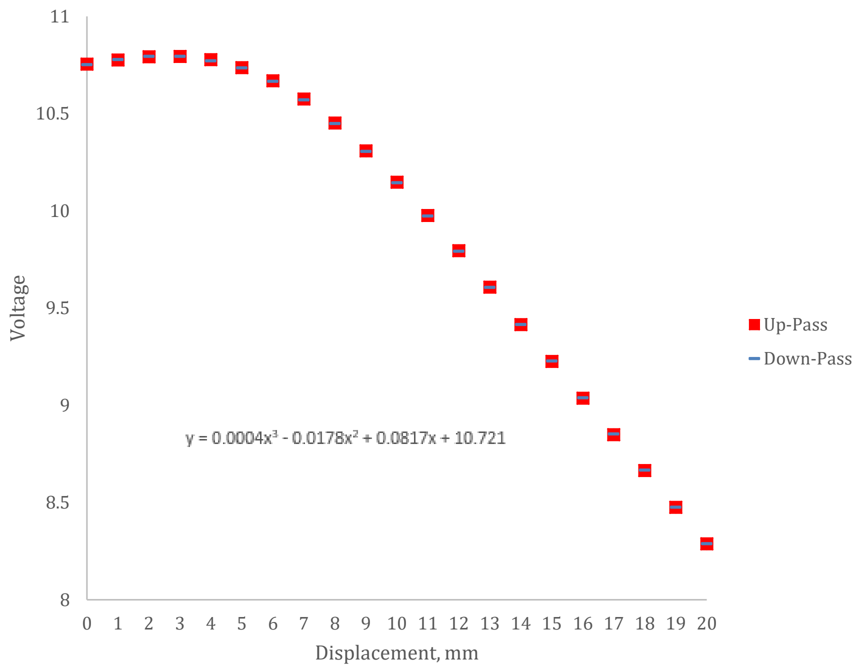

Figure 2 Experimental Data plot.

f.

The average voltage values for a given displacement was found using Eq. 1. This average was graphed in Excel and using the Excel best curve fit tool the best curve fit equation was found to be Eq. 3.

$$y = 0.0004x^3 - 0.0178x^2 + 0.0817x + 10.721 \qquad (3)$$

Equation 3 shows that the system is indeed a non-linear system as intended.

g.

The displacement that corresponds to $1.1426X10^1$ volts can be found using Eq. 3. This displacement is found to be 40.53mm using a cubic solver. Looking at Fig. 2 it is hard to imagine the voltage going back up; however, looking at Eq. 3 it is clear that this equation trends toward positive infinity.

5. Conclusions

h.

The objective of this experiment was to generate a calibration curve for a non-linear LVDT based measurement system that would allow for a more precise measurement of length. This experiment used the average of the up-pass and down-pass to generate the calibration curve. This eliminated the almost negligible hysteresis error that was present. The generated calibration curve and resulting equation of best fit allows for a more precise measurement of length. This calibration curve was successfully used to find 40.53mm is the expected displacement needed to achieve a voltage value of 11.426 volts.

6. Recommendations

Considering that this experiment had to be conducted virtually I would say that the experiment videos were well thought out and executed. I believe that this experiment lends itself to being conducted online given that there a minimum of tactile experiences one would receive even if the experiment were conducted in person. The one recommendation that I would make would be to re-record the videos with a better audio system as the noise of the air conditioning was overbearing.

Appendix A

Commented [LH1]:

Table I. Raw data				
displacement	voltage		displacement	voltage
0	10.7542		20	8.2876
1	10.776		19	8.47505
2	10.7925		18	8.6654
3	10.7941		17	8.8514
4	10.7771		16	9.0378
5	10.7367		15	9.2268
6	10.6689		14	9.4152
7	10.5748		13	9.60605
8	10.4514		12	9.79155
9	10.3083		11	9.97235
10	10.1474		10	10.1436
11	9.976		9	10.3042
12	9.79495		8	10.4474
13	9.6069		7	10.5695
14	9.41415		6	10.6647
15	9.22485		5	10.7343
16	9.03605		4	10.7705
17	8.84775		3	10.7943
18	8.6637		2	10.7927
19	8.4754		1	10.7766
20	8.2876		0	10.7501