University of Massachusetts Lowell

James B. Francis College of Engineering

Department of Mechanical Engineering

22.302 - Laboratory I

Section and Group number: ________________________

Experiment Number and Title: Experiment #______

LVDT and Accelerometer Calibration with Applications

Date of Experiment: March 9, 2004

Report Prepared by:

- Team Member #1 ____________________________
- Team Member #2 ____________________________
- Team Member #3 ____________________________

Instructors Comments: **Date of submission:** ....

Comments:

Introduction:

A transducer is a device that converts engineering quantities (pressure, temperature, displacement, velocity, acceleration, etc…) into electrical energy. Two types of transducers were calibrated in this experiment, one which measured displacement (LVDT) and one which measured acceleration (accelerometer). Before any transducers can be used for measurements, calibration must be performed. The following paragraphs outline the procedure and results of the calibration of an LVDT and accelerometer.

Objectives:

The objective of this laboratory experiment was to determine the sensitivities of both the LVDT and the accelerometer. In addition, familiarity was gained with common calibration equipment and procedure.

Discussion:

The calibration of the accelerometer was performed using an electrodynamic calibration shaker. The calibration shaker armature was able to compensate for the weight of the accelerometer and provide a constant 1 g_{rms} sinusoidal excitation signal at 100 Hz. With the input acceleration known, both an oscilloscope and multimeter then measured the electrical signal output from the accelerometer. From the accelerometer output data, the sensitivity of the accelerometer was determined to be 0.1785 V/g. For detailed procedure and results of this calibration refer to Appendix B.

The calibration of the LVDT was performed using a mounted micrometer fixture. Once properly secured and wired, the LVDT was then displaced in known increments along its usable range such that the corresponding output voltage for each increment could be recorded. The voltage data was then imported into Microsoft Excel where linear regression was used to determine the sensitivity of the LVDT. Figure 1 shows the calibration data for displacement both into and out of the barrel of the LVDT along with the sensitivity of the LVDT, which was calculated to be 1.3731 V/in. For additional plots and procedures of the LVDT calibration refer to Appendix C.

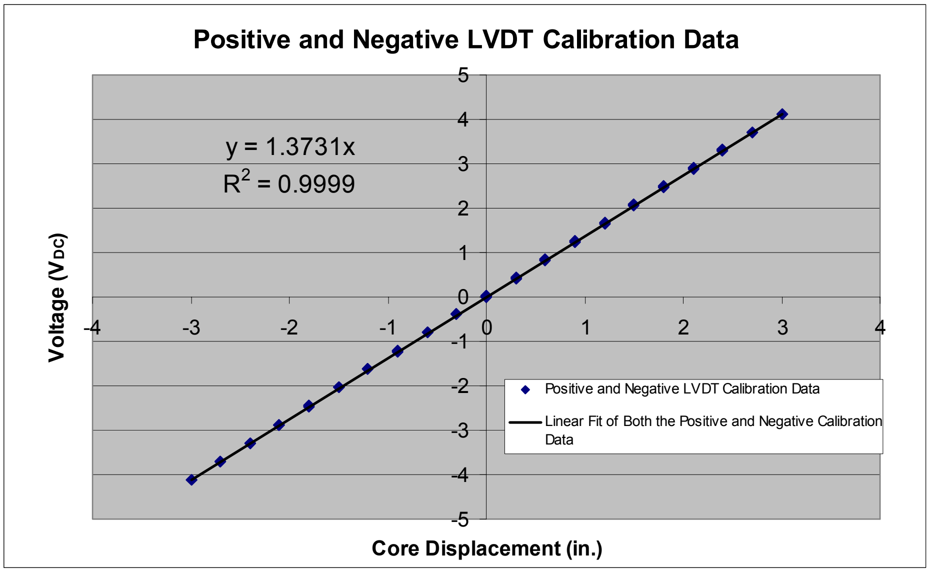

Figure 1. LVDT Calibration incorporating both positive and negative portions of the calibration. Sensitivity is taken as the slope of this plot.

Conclusions:

The lab was successful in showing how to correctly calibrate an LVDT and accelerometer. In addition, valuable experience was gained in setting up, executing, and processing data from a common transducer calibration.

Recommendations:

To improve on the quality of the data taken during the calibration of the LVDT it is advised that a redesign of the micrometer fixture be investigated. The current micrometer fixture made it very difficult to secure the LVDT such that no movement occurred during the calibration.

References:

1. Avitabile, Peter. LVDT and Accelerometer Calibrations with Applications. Lab Handout. 01/11/2002.

<u>Appendix A:</u>

Post-Lab Questions

1. Define the term sensitivity as it relates to a transducer.

   Answer here…

2. Define what the null position of an LVDT is.

   Answer here…

3. Determine the sensitivity of the LVDT. Generate a plot of the output voltage vs. input displacement of the core.

   Answer here…

4. If the LVDT has a linear input range of +/- 3 inches with a corresponding output range of +/- 10 Vdc, what nominal sensitivity should this instrument have?

   Answer here…

5. Is the calibrated sensitivity different from the expected value? Why may these values differ?

   Answer here…

6. Determine the sensitivity of the accelerometer.

   Answer here…

7. What means can be used to determine if the accelerometer was calibrated at 100Hz?

   Answer here…

8. How accurate are the experimental sensitivities of the LVDT and accelerometer? Discuss the sources for error.

   Answer here…

9. Discuss an alternate means of calibrating an accelerometer.

   Answer here…

Appendix B

Accelerometer Calibration Procedure and Results

An electrodynamic shaker, seen in Figure B1, was used in conjunction with a multimeter and oscilloscope to calibrate the accelerometer. By recording the voltage output of the accelerometer in response to the shaker's constant input acceleration (1 g_{rms}), the sensitivity was easily determined. (The data and sensitivity calculation can be seen in Tables B1 and B2, respectively.)

Calibration Procedure (Portions adapted from [1]):

1. Connect the accelerometer to the calibration equipment as shown in Figure B1. The accelerometer should be connected to the XDCR connector on the rear of the power supply using a microdot cable.

2. Determine if the power supply of the shaker is functioning properly. Turn the left knob to the battery test position. Verify that the shaker power is sufficient by observing if the needle moves into the graduated area.

3. Set channel 2 on the oscilloscope to DC coupling. Adjust the vertical scale to 0.2 volts/div.

4. Test the response of the system by gently tapping the bottom of the accelerometer. Note the polarity of the signal on the oscilloscope. Tap the top of the accelerometer and note the resulting polarity of the signal.

5. Place a small amount of wax on the center of the accelerometer disk. Carefully attach the base of the accelerometer to the disk with a slight twisting motion.

6. Turn the power supply of the accelerometer and the accelerometer on.

7. Measure the V_{pp}, V_{rms}, and period of oscillation of the transducer output with the oscilloscope and multimeter.

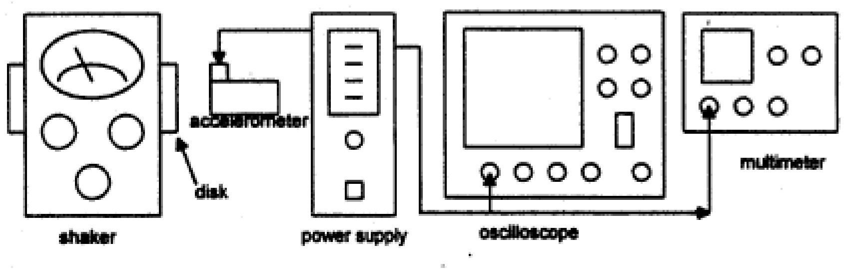

Figure B 1. Accelerometer calibration using the electromechanical shaker along with multimeter and oscilloscope.

Table B 1. Oscilloscope and Multimeter output values from the calibration of the accelerometer.

Multimeter		**Oscilloscope**		
Vout (rms)		Vpp	T (sec.)	Frequency (Hz)
0.1785		0.505	0.01	100

Table B 2. Calculation of accelerometer sensitivity.

Sensitivity	=		.1785 V/g			
g =	32.1742		ft/s^2	=	386.0904	in/s^2
Sensitivity	=		0.000462327	$V/(in/sec^2)$		

Appendix C:

LVDT Calibration Procedure and Results

The LVDT used in the experiment had the following specifications:

Operating Temp.	0 – 160 deg F
Null Voltage	0 V_{DC}
Linearity	0.25% full scale
Freq. Response (-3 dB)	200 Hz

The calibration of the LVDT required a +/- 15 V DC power supply and a mounted micrometer setup, which can be seen in Figure C1.

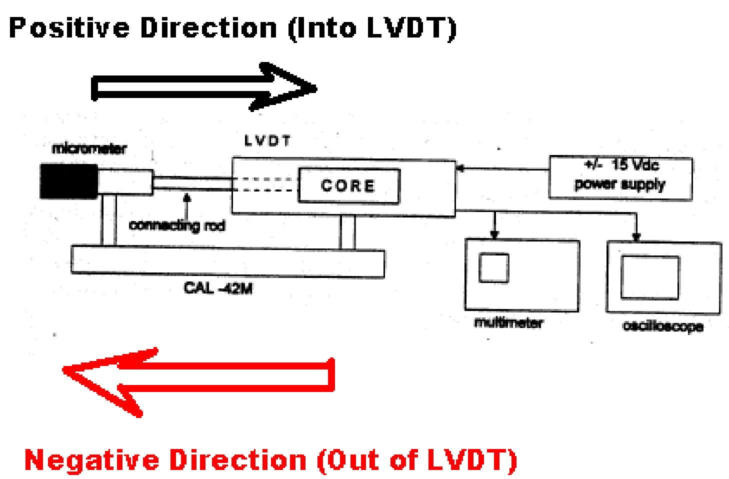

Figure C 1. Setup of the LVDT and Accelerometer indicating the measurement direction.

This data was recorded for two separate situations, where the first situation was the LVDT connecting rod moving into the LVDT (positive) and the second situation was the connecting rod moving out of the LVDT (negative). By combining the data from the positive and negative calibration procedures, the sensitivity over the entire linear range (+/- 3 in.) was found. The entire linear range sensitivity differed from the positive and negative range sensitivities by only 0.3% and 0.4% respectively. Since these differences were minimal, the sensitivity over the entire range was used for the final calibration. The data and plot for the positive range can be seen in Table C1 and Figure C2 respectively, and the data and plot for the negative range can be seen in Table C2 and Figure C3 respectively. The final sensitivity plot, denoting a sensitivity of 1.3731 V/in., can be seen in Figure 1.

Calibration Procedure (Adapted from [1]):

1. Adjust the micrometer screw of the calibration fixture to the middle zero position. The micrometer has a marked travel of 3 inches with a resolution of 0.001 inches.

2. Attach the core connecting rod to the micrometer and to the core.

3. Install the LVDT in the calibration fixture. Use the adapting sleeves to shim the LVDT as necessary.

4. Verify that the LVDT power supply is off. Connect the LVDT to the power supply using the “D” to bendix cable. Connect the output from the transducer to the input of the multimeter and oscilloscope. Turn on the power supply

5. Adjust the LVDT in the fixture to the null position. An output of zero volts should be observed on the multimeter in the DC mode. Tighten the LVDT to the fixture. Verify that the micrometer is still at the middle zero setting.

6. Adjust the micrometer an amount that displaces the core three tenths of an inch (four complete revolutions of the micrometer screw). Record the distance and output voltage. Repeat this process with measurement intervals of three tenths of an inch for a total travel of three inches.

Table C 1. LVDT calibration data from displacing connecting rod into LVDT core (positive).

Δx (in.)	V_{DC}
0	0
0.3	0.405
0.6	0.8235
0.9	1.233
1.2	1.647
1.5	2.061
1.8	2.4615
2.1	2.8845
2.4	3.294
2.7	3.7035
3	4.1175
2.7	3.7035
2.4	3.3255
2.1	2.9205
1.8	2.5065
1.5	2.097
1.2	1.6875
0.9	1.2645
0.6	0.846
0.3	0.45
0	0.036

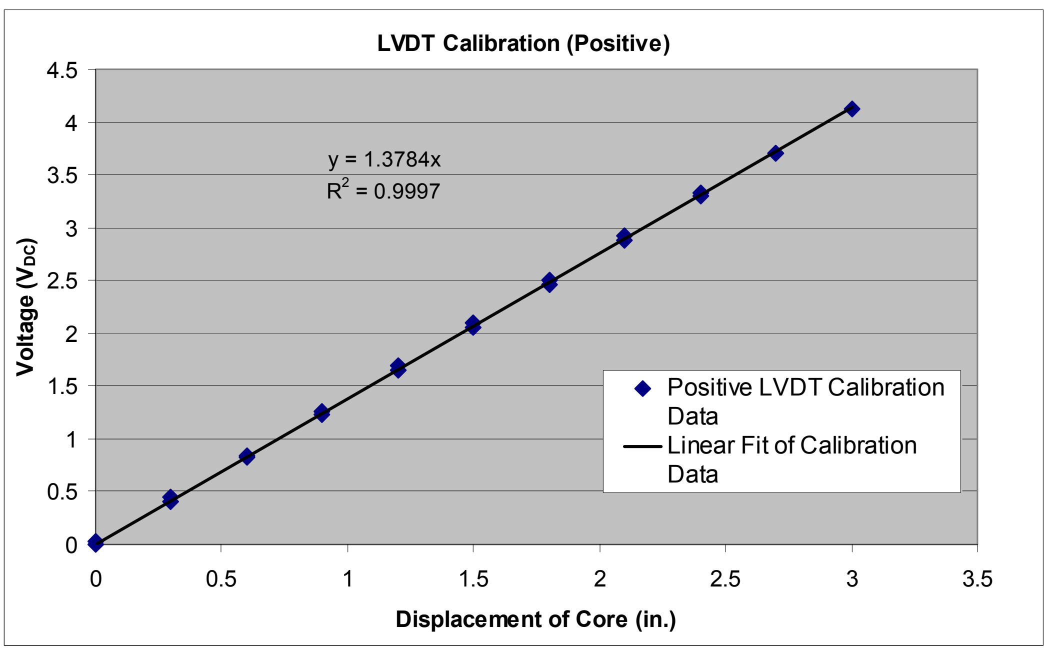

Figure C 2. Positive LVDT calibration plot with linear fit.

Table C 2. LVDT calibration data from displacing connecting rod out of LVDT core (negative).

Δx (in.)	V_{DC}
0	0.036
-0.3	-0.378
-0.6	-0.792
-0.9	-1.242
-1.2	-1.6155
-1.5	-2.034
-1.8	-2.4525
-2.1	-2.871
-2.4	-3.2895
-2.7	-3.7035
-3	-4.1175
-2.7	-3.7125
-2.4	-3.294
-2.1	-2.88
-1.8	-2.457
-1.5	-2.0385
-1.2	-1.62
-0.9	-1.2195
-0.6	-0.7965
-0.3	-0.378
0	0.0135

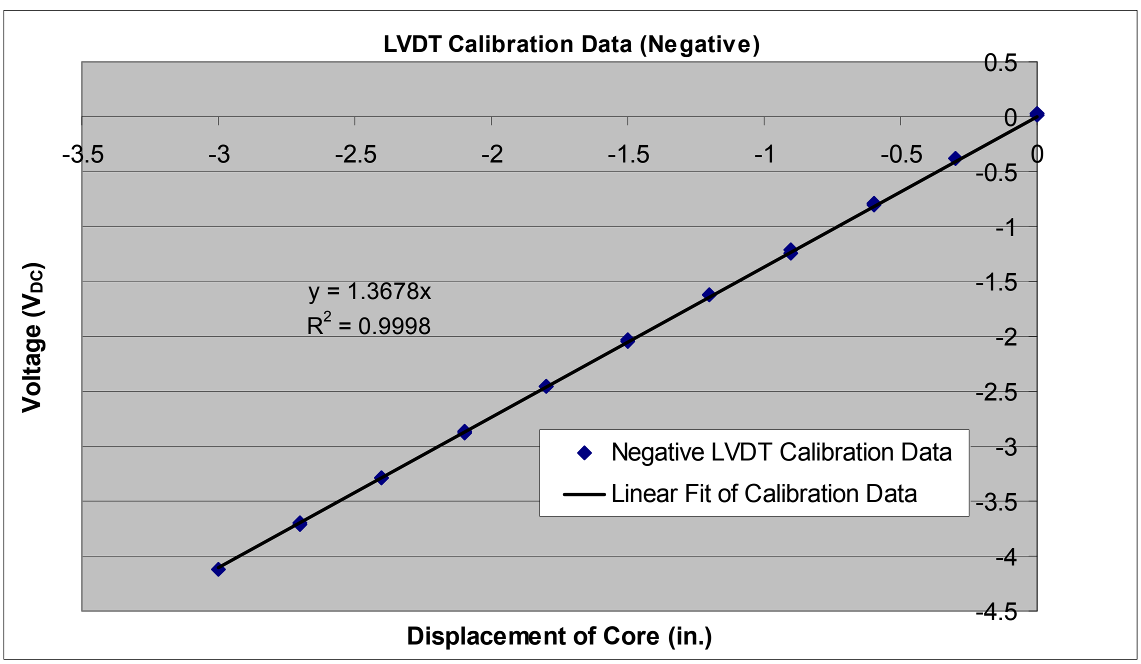

Figure C 3. Negative LVDT calibration data with linear fit.

Appendix D:

Equipment Used

Model	Serial Number	Description
UML LVDT ±15V	CAL-42M	Linear Variable Displacement Transducer
Nat'l Instruments	002540	50 Pin Ribbon
Tektronix 2225	16666251145134	50 Mhz Oscilloscope
1557-A	2882	Vibration Calibrator
Fluke 8010A Digital Multimeter	4380137	Digital Multimeter

Appendix E:

Lab Notebook

Correlation of Shock Absorber Displacement and Acceleration Response

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Equipment	S/N	Model	Manufacturer
± 15 V DC PWR Supply	1591-D	—	Hammond
Power Supply	237	433A03	PCB
Digital Multimeter	4380137	8010A	Fluke
50 MHz Oscilloscope	2225-D010452	2225	TekTronix
12-Bit A/DC Board	002540		
LVDT	435N	1000HCD	Schaevitz Engineer
Accelerometer	19090	330A	PCB
Electromechanical Shaker	1071	394B06	PCB
Spring/Strut/Axle Assembly	—	—	BMW
Steel Support Structure	5793-UML	—	UMASS-Lowell
Shaker Table	A16492	5795-AD	PMC Beta

Setting of Equipment

Digital Data Acquisition System (DAS) - LabView is being used

- Ch 0 → LVDT Data
- Ch 1 → Accelerometer Data
- Sample Rate 1600 sample/second ⇒ 3200 total samples taken

Oscilloscope - Initial Settings

Vertical Scale = 0.2 V/division

Channel 2 set at DC coupling

Multimeter - DC Mode

03/12/04 - 5

[signature]

T.A. [signature]

03/12/04 – 6

Calibration of LVDT

Note: Multimeter is zeroed – Reading is 0.00 V initially.

Displacement of Core into LVDT

ΔX (in.)	V (DC)
0	0 (CMD 03/12/04)
0.1	~~0.10~~ 0.135
0.2	0.2745
0.3	0.411
0.4	0.549
0.5	0.687
0.6	0.8205
0.7	0.9615
0.8	1.098
0.9	1.2345
1.0	1.3725
0.9	1.2345
0.8	1.1085
0.7	0.9735
0.6	0.8355
0.5	0.699
0.4	0.5625
0.3	0.4215
0.2	0.282
0.1	0.15
0	0.012

Note: → Slight offset upon return to starting position.

Estimate of Sensitivity of LVDT – Positive

$\frac{\Delta V}{\Delta x} = \frac{1.3725 V}{1 in} = 1.3725 \frac{V}{in}$

03/12/04-6
[illegible]
TA. [illegible]

Calibration of LVDT (cont) 03/12/04 - 7

Note: Multimeter has initial DC value of 0.012 V ~~zero reading - No adjustments needed~~ CMD 03/12/04

Displacement of Core out of LVDT

ΔX (in)	V (DC)
0	0.012
-0.1	-0.126
-0.2	-0.264
-0.3	-0.414
-0.4	-0.5385
-0.5	-0.678
-0.6	-0.8175
-0.7	-0.957
-0.8	-1.0965
-0.9	-1.2345
-1.0	-1.3725
-0.9	-1.2375
-0.8	-1.098
-0.7	-0.96
-0.6	-0.819
-0.5	-0.6795
-0.4	-0.54
-0.3	-0.4065
-0.2	-0.2655
-0.1	-0.126
0	0.0045

Estimate of Sensitivity of LVDT - Negative

$$\frac{\Delta V}{\Delta X} = \frac{1.3605\ V}{1\ in} = 1.3605\ \frac{V}{in}$$

← Value is close to positive calculation ✓

03/12/04 - [signature]

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Calibration of Accelerometer 03/12/04 - 8

Note: Electromechanical Shaker is badly dented - possible damage

Bonding solution is used to secure accelerometer to the top of the shaker.

Multimeter Reading: ⇒ 0.1785 V(rms)/grms

Oscilloscope → V_{pp} = 0.505
~~Period T =~~ CMD 03/12/04

Scale on O'Scope adjusted to 0.05 V/div
0.002 ms/div

Estimate of ~~period~~ → ~~3.4~~ 3.35 → 3.4 divisions.
T ≈ 0.0067

$\frac{1}{T} = f \approx 150\ Hz$

Execution of Experiment

Labview Data Stored on CMD's Floppy in ME Lab I folder

Filenames:
"Test I" and "Test II"

Observation: Lot of squeaking of the joints on support structure
Room shaking violently
Spring is very worn and rusted
~~Used Lubricant in~~

03/12/04
[signature]
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