Lab 1: Pressure Transducer Calibration and Hysteresis

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I. Introduction

This is a report on the data collected in session one on Wednesday, January 24th that analyzes the pressure and current recorded from both the transducer and manometer while varying the flow velocity in the wind tunnel. Two sets of data were recorded, one while increasing flow velocity, and one while decreasing the flow velocity. Over the course of the report, these two sets of data will be compared and hereafter referred to as simply ‘increasing’ or ‘decreasing’.

II. Manometer Pressure Calculation

Manometer pressure values, were calculated in Pascals using equation (1), where *h* is the recorded height of the manometer, adjusted for the initial offset. The density of water used was 997.71 kg/m^3, while the gravitational constant used was 9.81 m/s^2.

$$P_{manometer} = \boldsymbol{\rho}_{\mathbf{water}} \boldsymbol{g} \boldsymbol{h} \tag{1}$$

III. Analysis of Data for Hysteresis

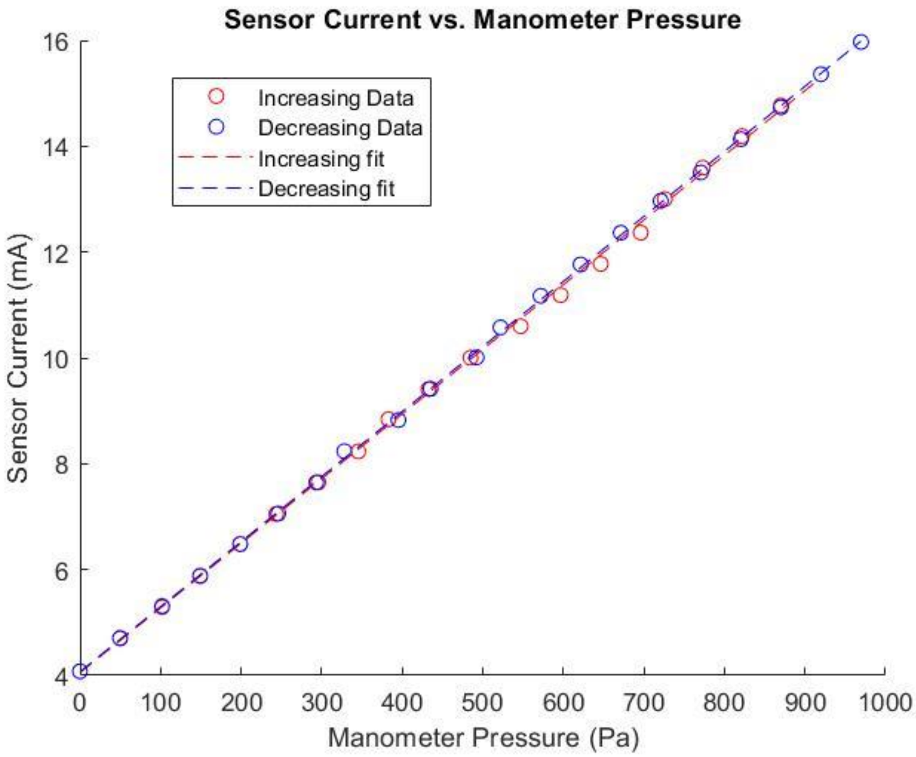

Figure 4. Sensor Current vs. Manometer Pressure. *Shows the linear regressions for both the increasing and decreasing data sets when plotting current against pressure. The slopes of the regression lines are the calibration factors, which, if close, mean that the system is well calibrated and there is little or no hysteresis.*

The calibration factors of the increasing (2) and decreasing (3) data sets are represented by the slope of the corresponding line of best fit in Fig. 4, which plots sensor current against manometer pressure.

$$\mathrm{y} = 0.0122 * \mathrm{x} + 4.0518 \tag{2}$$
$$y = 0.0123 * x + 4.0695 \tag{3}$$

These two slopes differ only by 0.816%, as shown through the percent difference equation (4), indicating that if hysteresis is present, it is minimal. The slopes here are represented by variable *m*.

$$^{3}Percent\ difference = \frac{|m_{increasing} - m_{decreasing}|}{|\frac{m_{increasing} + m_{decreasing}}{2}|} \tag{4}$$

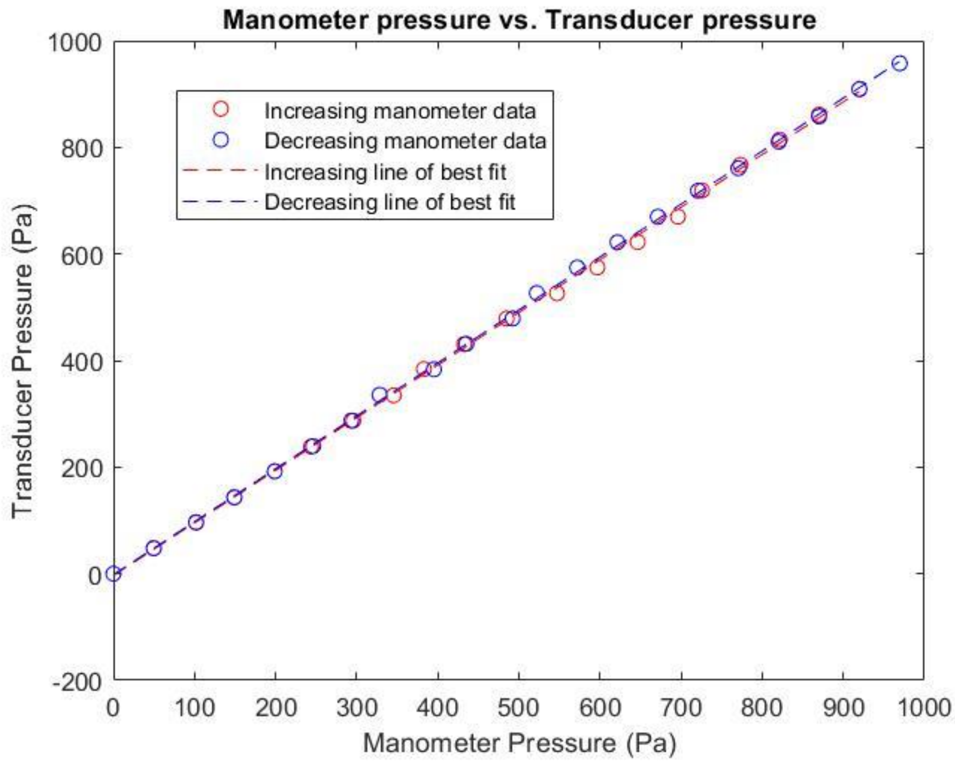

Figure 1. Manometer Pressure vs. Transducer Pressure. *Shows the linear regressions for both the increasing and decreasing data sets when plotting manometer pressure against transducer pressure. The slope of the linear lines should be equal to one if there is no discrepancy between the sets of data*

Fig. 1, which plots transducer pressure readings against the manometer pressure readings, reinforces the idea that the data lacks hysteresis. The linear regression slopes should equal one in this case if the transducer data are identical to the manometer data, but as the data are not identical, the slopes as shown by equations (5) and (6) instead equal 0.9874 and 0.9933, for the increasing and decreasing sets, respectively. While these calibration factors are not exactly equal to one, they are extremely close, each being only a couple hundredths off, illustrating the negligibility of the data variation.

$$y = 0.9874 * x - 3.3743 \quad (5)$$
$$y = 0.9933 * x - 1.7110 \quad (6)$$

To be thorough, if calculated using the lines of best fit for the calibration curves in Fig. 4, there is approximately only 0.567% hysteresis for the entire data set. To calculate approximate hysteresis, the lines of best fit for the increasing and decreasing data sets were used as a basis. The midpoint between the first and last data point was found with the midpoint equation (7), and then the hysteresis was calculated with the hysteresis percentage equation (8).

$$^{4}x_{midpoint} = \frac{x_{max} - x_{min}}{2} + x_{min} \quad (7)$$

$$^{1,2,4}Hysteresis\ Percentage = \left|\frac{y_{midpoint\ upper} - y_{midpoint\ lower}}{y_{max} - y_{min}}\right| * 100 \quad (8)$$

Where values were not the same between increasing and decreasing sets, the average of the two was used. The y-values for the upper and lower midpoints refer to the linear regressions, and as shown in Fig. 4, the upper regression corresponds to the decreasing data set. The x-value for the midpoint was used to calculate both midpoint y-values in junction with the linear regression equations (2) and (3). The values used for the calculations are as follows, with the x-values being pressure in Pascals, and the y-values being current in milliamps:

$x_{max} = 919.8325$, $y_{max} = 15.36$, $x_{min} = 0$, $y_{min} = 4.0785$

$y_{midpoint\ upper} = 9.727$, $y_{midpoint\ lower} = 9.663$

It should be noted that total hysteresis is typically calculated with two parallel lines, and in this case the lines of best fit are not parallel; however, the lines differ only slightly, so they were used for this approximate hysteresis calculation. With the variation in the calibration factors at a near-negligible level already, an estimation of hysteresis is suitable. Calculation shows that hysteresis is not present, as the percentage is small enough that other factors are likely the cause of the inconsistencies between the increasing and decreasing data sets.

IV. Sources of Error

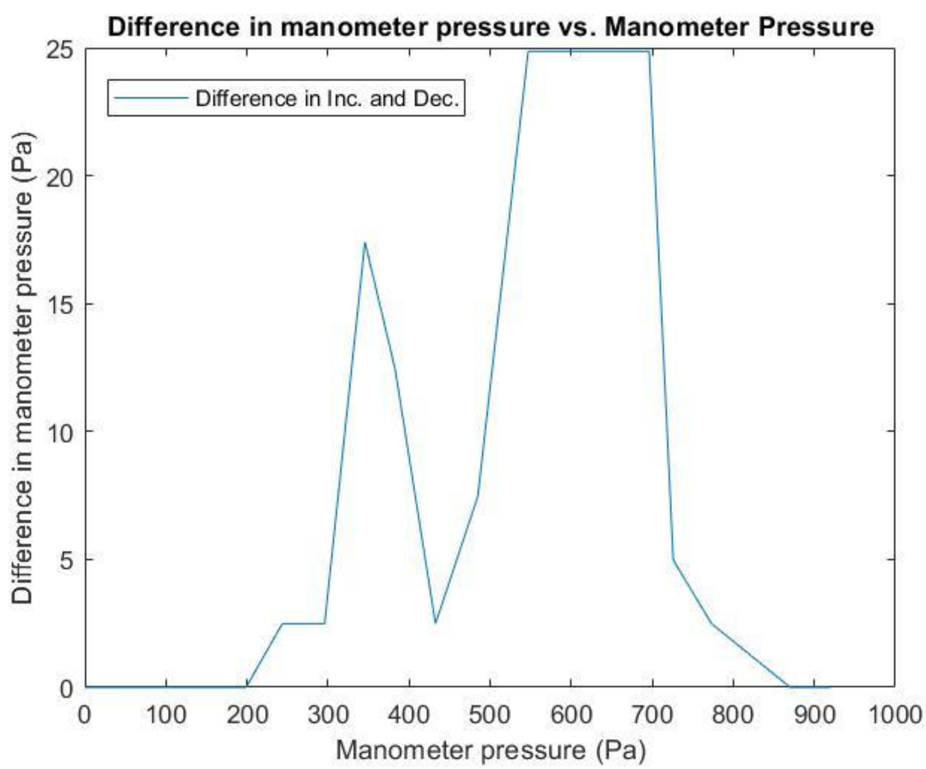

Figure 3. Manometer Pressure Difference. *Displays the total (absolute value) difference in manometer pressure plotted against manometer pressure to show the discrepancy between the increasing and decreasing data sets.*

Knowing the method of data collection involved reading from the manometer and adjusting propeller tilt, which both were not entirely exact, the low level of hysteresis can likely be attributed to human error and slight variations in flow. In Fig. 3**,** the difference in the manometer readings from increasing to decreasing can be seen to increase significantly at around the 600 Pascal mark. This difference does not take the transducer into account, and as it is only comparing the manometer readings, it shows that primarily the variation in the data occurred because of the human-recorded manometer data.

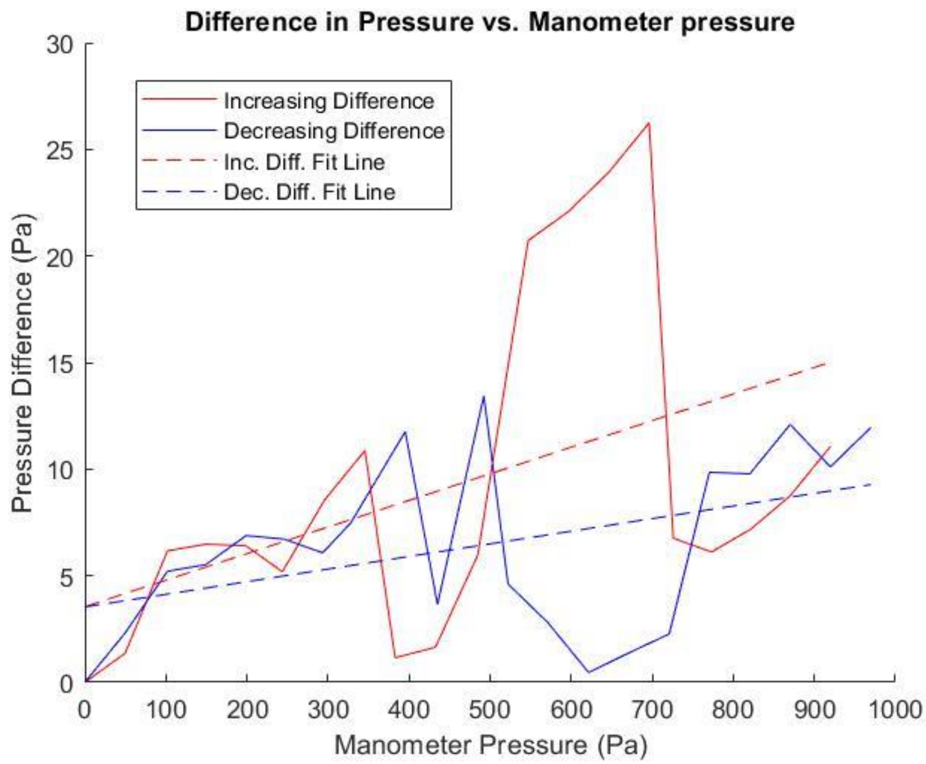

Figure 2. Difference in Pressure vs. Manometer Pressure. *Illustrates the total difference in manometer and transducer pressure plotted against manometer pressure. Compare with Fig. 3 to notice the similarities in primary areas of difference.*

Fig. 2 also shows a difference in pressure reading, but instead compares the difference between the transducer and manometer readings. In combination, the figures portray that there was some inaccuracy in the transducer readings, but the inaccuracy can be mainly attributed to the manometer error, as the same spike in difference can be seen at around the 600 Pascal mark.

V. Accuracy of Transducer Calibration

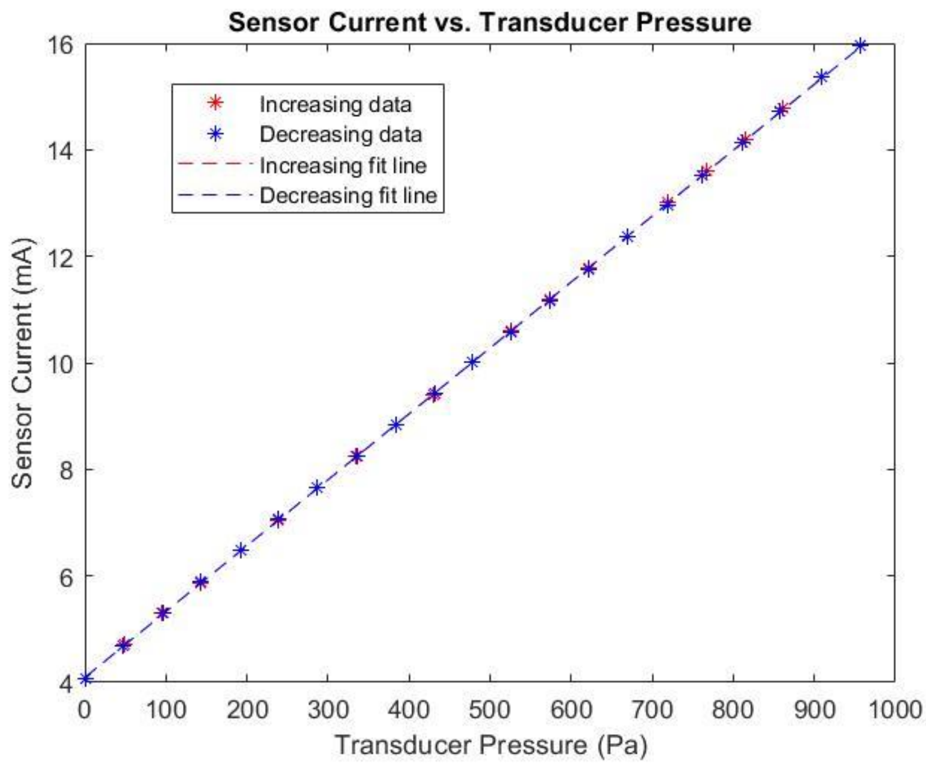

Figure 5. Sensor Current vs. Transducer Pressure. *Compares the two almost identical linear fits of the increasing and decreasing data recorded from the transducer, indicating correct calibration.*

Looking at the transducer readings alone, represented in Fig. 5, there is almost no distinction between the two lines of best fit, each having almost the same slope, which further indicates that the main source of error was in the manometer readings. Lack of distinction between the two calibration factors for the transducer data also indicates that the device is calibrated correctly, as it displays even less of a sign of hysteresis than that of the manometer data. The linear fit equations for the increasing and decreasing transducer data are represented by equations (9) and (10), in which the slopes are equal, and the intercept values differ by only two-thousandths.

$$y = 0.0124 * x + 4.0933 \tag{9}$$
$$y = 0.0124 * x + 4.0910 \tag{10}$$

VI. Appendix