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Subject: Wind Tunnel Calibration and Performance

Introduction

The objective of this lab was to calibrate the multiport pressure transducer, calibrate the wind tunnel venturi and determine the velocity distribution at 75% dial based on empirical displacement thickness model and also to determine if a drag plate will affect our venturi calibration.

To determine the velocity in the wind tunnel, the following equations were used:

Bernoulli's Equation- Conservation of Energy

$$P_0 = P_1 + \frac{\rho V_1^2}{2} \tag{1}$$

Continuity Equation – Conservation of Mass

$$A_1V_1=A_2V_2 \tag{2}$$

Pitot-Static Probe

$$V = \sqrt{\frac{2q}{\rho}} \tag{3}$$

Drag Force

$$D = \frac{C_D \rho A v^2}{2} \tag{4}$$

Using equations (1) and (2), venturi calibration equation is achieved.

$$\Delta P = Kq \tag{5}$$

Where ΔP is pressure difference, K is the Area constant and q is dynamic pressure. The empirical boundary layer equations were used to get Reynolds number and displacement thickness. Equation 4 was used to find the drag coefficient (C_D) of the plate.

Procedure

The experiment used several pieces of equipment, including a wind tunnel, barometer, thermometer, manometer, pump, power box, speed adjust dial, pitot-static probe, ruler, marker, LabView DAQ, hot-wire anemometers, and pressure transducer. The wind tunnel was used to move air through a large tube, and the other instruments were used to measure pressure, temperature, and velocity. Data was collected and used to calibrate the equipment and determine the boundary layer thickness and displacement thickness. LabView DAQ was used to record the data collected. A hot-wire and pressure transducer were used to measure instantaneous flow velocity and fluid pressure.

Results and Discussion

Lab 1

In table 1, the calibration constant represents the slope for the values from each channel. From CH 0 to CH7, all values seem the same because they are measuring pressure in same units.

Table 1 – Transducer Calibration Constants

DAQ Channel	Measured Quantity	Pressure Channel	Calibration Constant	Units
CH 0	Temp.	x	10	Deg. F / Volt
CH 1	Static P.	CH 1	-31.05662	PSF / Volt
CH 2	Total P.	CH 2	-31.09121	PSF / Volt
CH 3	Static P.	CH 3	-30.98594	PSF / Volt
CH 4	Total P.	CH 4	-30.86008	PSF / Volt
CH 5	Static P.	CH 5	-30.9789	PSF / Volt
CH 6	Total P.	CH 6	-30.94102	PSF / Volt
CH 7	Static P.	CH 7	-31.01491	PSF / Volt
CH 8	Force	x	-1.640839	lb / Volt

These calibration constants were used to change the voltage readings into values which then were used in different equations. After processing the Wind tunnel Venturi Data using these calibration constant, Figure 1 was made which shows the dynamic pressure vs. change in pressure. The slopes of this graph, which is K, were then plotted against distance between a point in test section and the wind tunnel inlet. Figure 1 also shows that the K for all these slopes were close to one.

In Figure 2, K_{exp} was compared with $K_{theo,}$ which was computed using Empirical Boundary Layer Equations. For K_{theo}, that little bump in the graph shows that the Empirical Boundary Layer Equations switched from Laminar to Turbulent Boundary Layer.

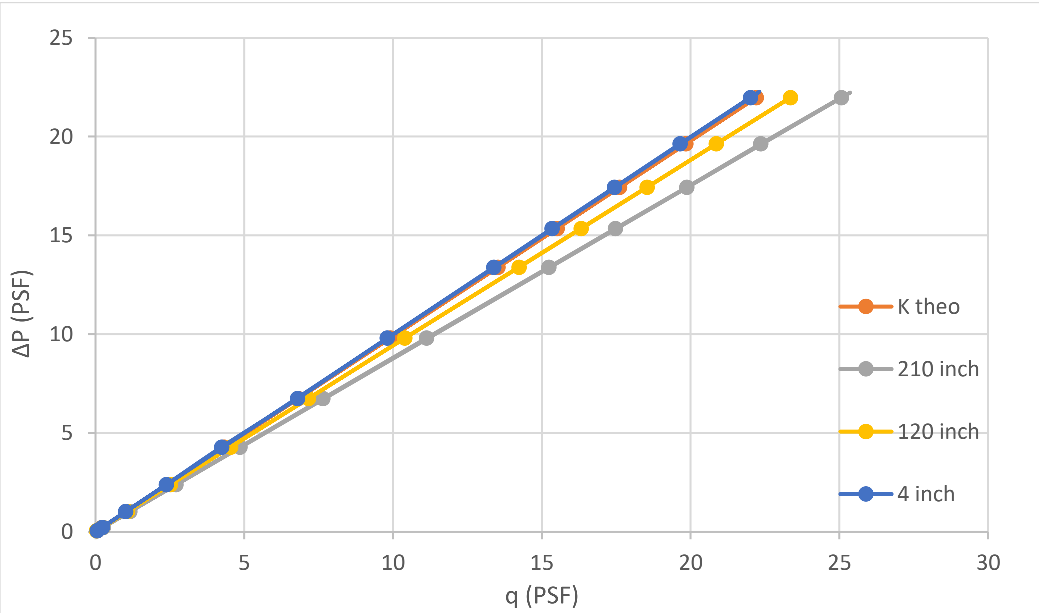


Figure 1. Dynamic Pressure vs. Change in Pressure

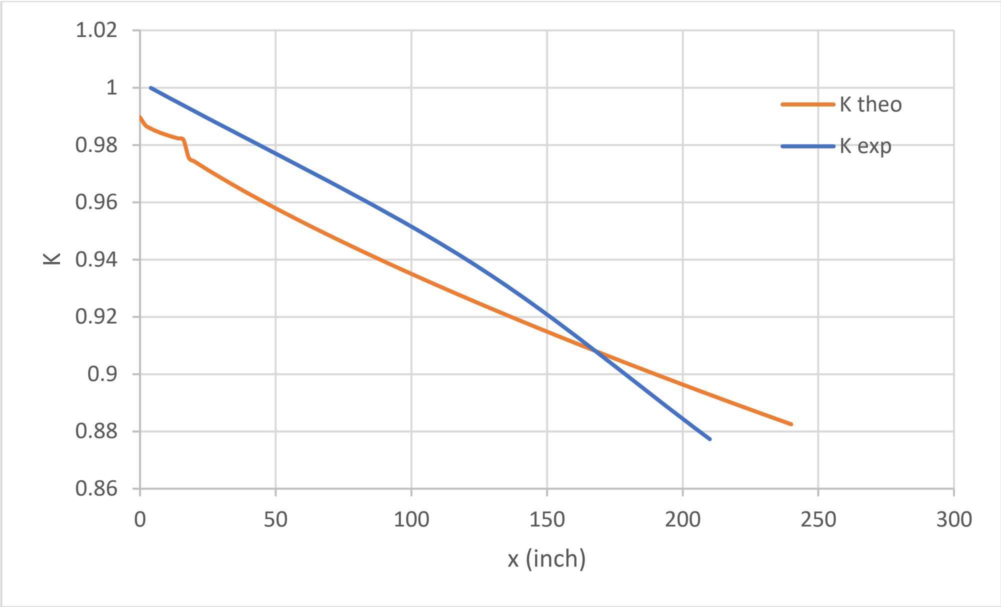


Figure 2. K_{gen} Theoretical vs. K_{gen} Experimental

In figure 3, the Empirical Boundary Layer Equations were used to get theoretical velocities which were then plotted with experimental velocities which were processed using K_{exp} for each distance. Again, the little bump for Empirical Model shows that boundary layer has switched from laminar to turbulent flow.

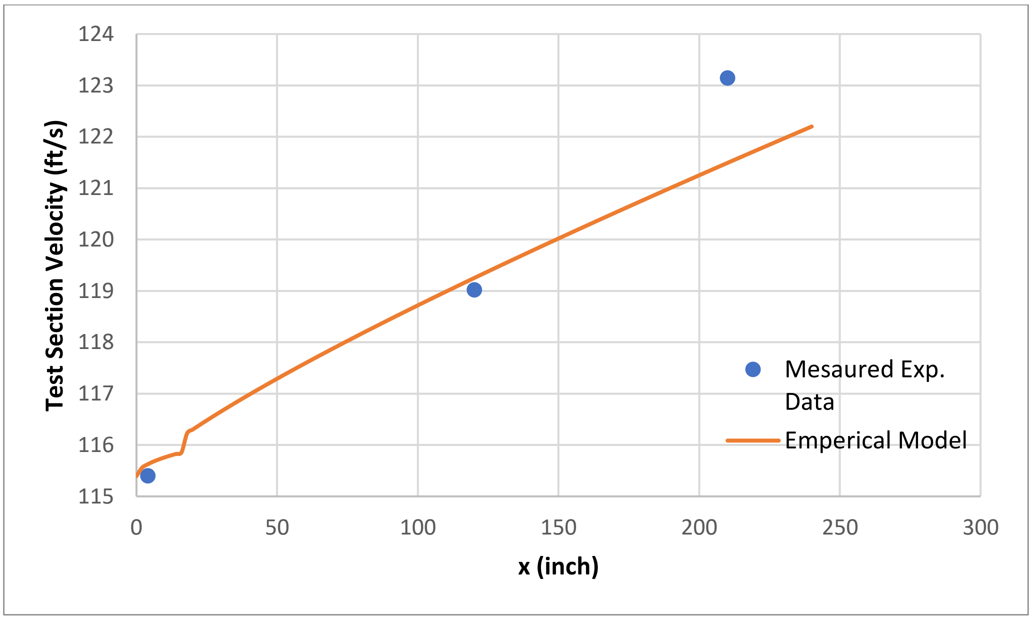


Figure 3. Measured velocity vs. Empirical Model Velocity

To find drag coefficient for the drag plate, the data from DV sheet was used to compute C_d at six different velocities of Test section. Looking at figure 4, the value of C_d is rising very slowly with increase in velocity. If this drag plate was added 4 inches away from inlet, the graphs in Figure 1 and Figure 2 will change. The K value will decrease because of pressure difference and dynamic pressure. Because of this, in Figure 2, the graph will become more hyperbolic, meaning that K_{exp} will come closer to K_{theo}.

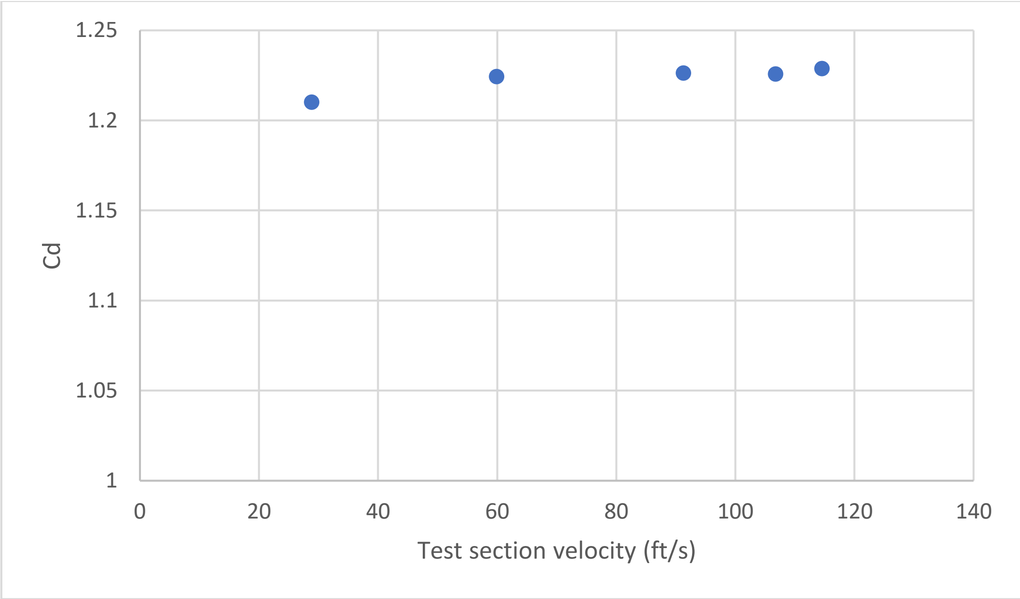
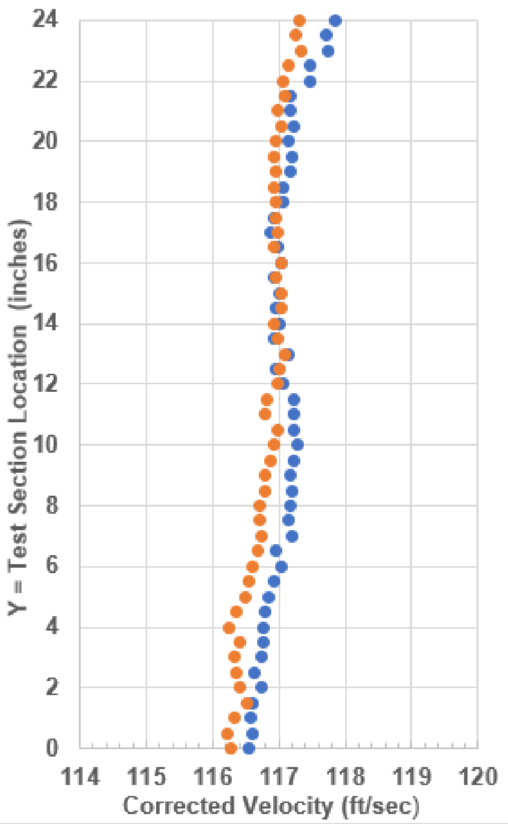


Figure 4. Drag coefficient vs. Test Section Velocity

Lab 2

During Lab 1, the air velocity was determined by utilizing the pitot-static tube. In contrast, Lab 2 explored a different approach to calculating velocity, using a hotwire, and observing the changes in temperature. The velocity changes were represented by the orange points when the hotwire moved upwards and the blue points when it moved downwards within the wind tunnel, as illustrated in the figure 5 and 6 below.



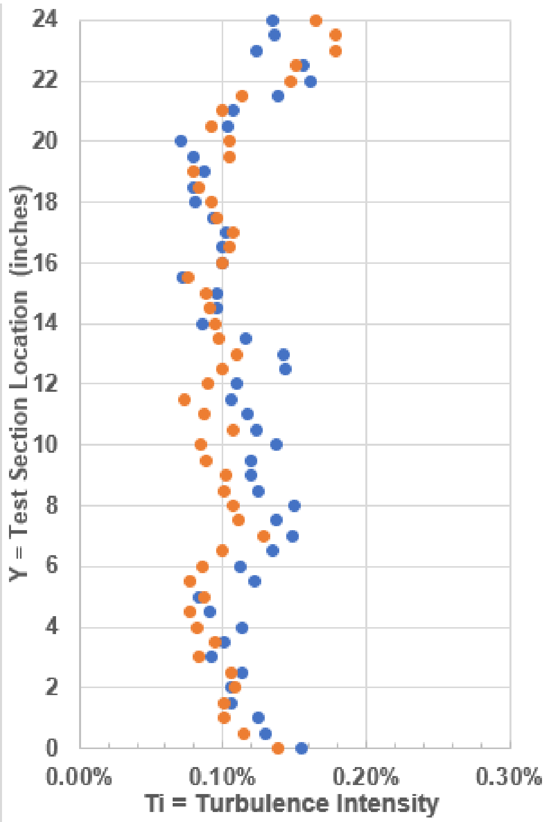


Figure 5. Temp Corrected Velocity Profile

Figure 6. Turbulence Intensity Profile

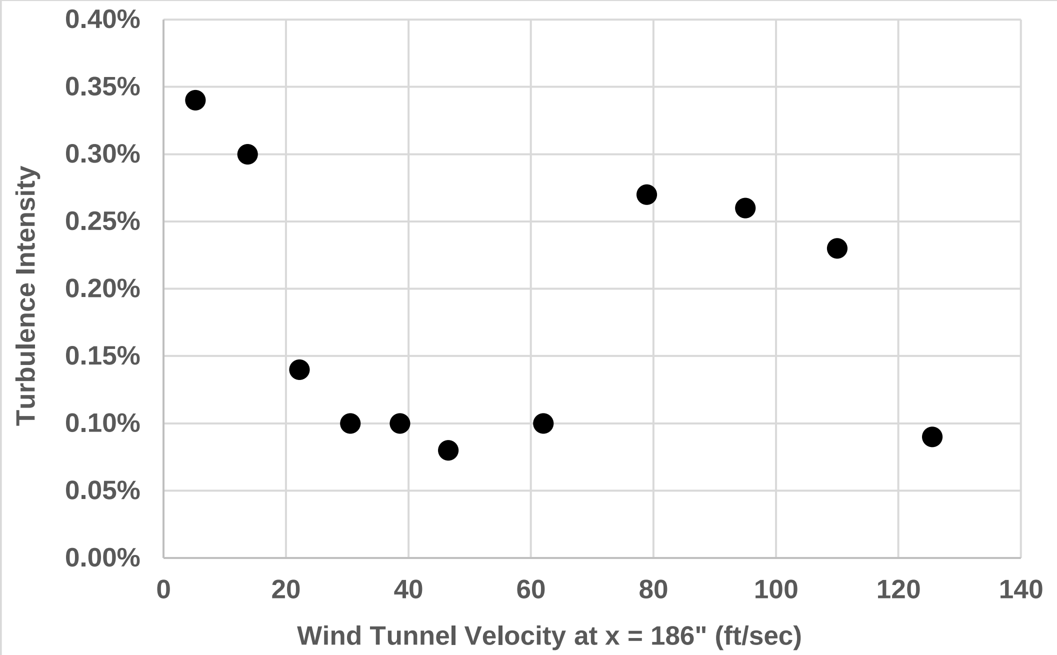


Figure 7. Turbulence Intensity as a function of Wind Tunnel Velocity

Conclusion

the purpose of this lab was to perform various calibrations, including calibrating the multi-port pressure transducer's nine channels and the wind tunnel venturi, as well as measuring the experimental boundary layer and displacement thickness at three different points at 75% dial setting and the objective was achieved. The Wind Tunnel velocity in test section was determined using equations, a pitot-static probe, and a hotwire, and the K after completing the necessary calculations. However, our group encountered a challenge during the processing of lab data where we struggled to achieve a proper value of K because of PSF at 4,120 and 210 inches. We were getting odd numbers, when we compared it with the graphs and theoretical values got from empirical boundary layer equations, which did have an impact while calculating K and velocity.