Quantitative Data Analysis for Wind Tunnels

EGR 250 Spring Semester

Union University: Engineering Department

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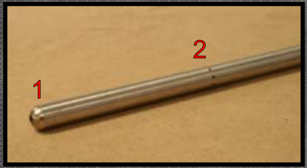
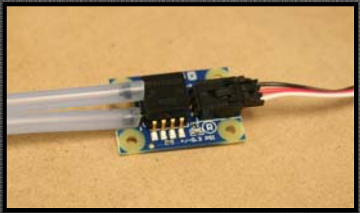


I. Pitot Static Tube

A Pitot (pē-tō) Static Tube is used to measure pressure in air-flow. It has two openings: a hole in the front that measures stagnation pressure (location 1 in picture above) and a set of holes further back that measure static pressure (location 2). We utilize these two measurements using Bernoulli's Equation, which relates the difference of these pressures to the flow velocity of the air. Manipulating Bernoulli's original equation, velocity is related to pressure by the following relation:

$$v = \sqrt{\frac{2P_{DIFF}}{\rho}}$$

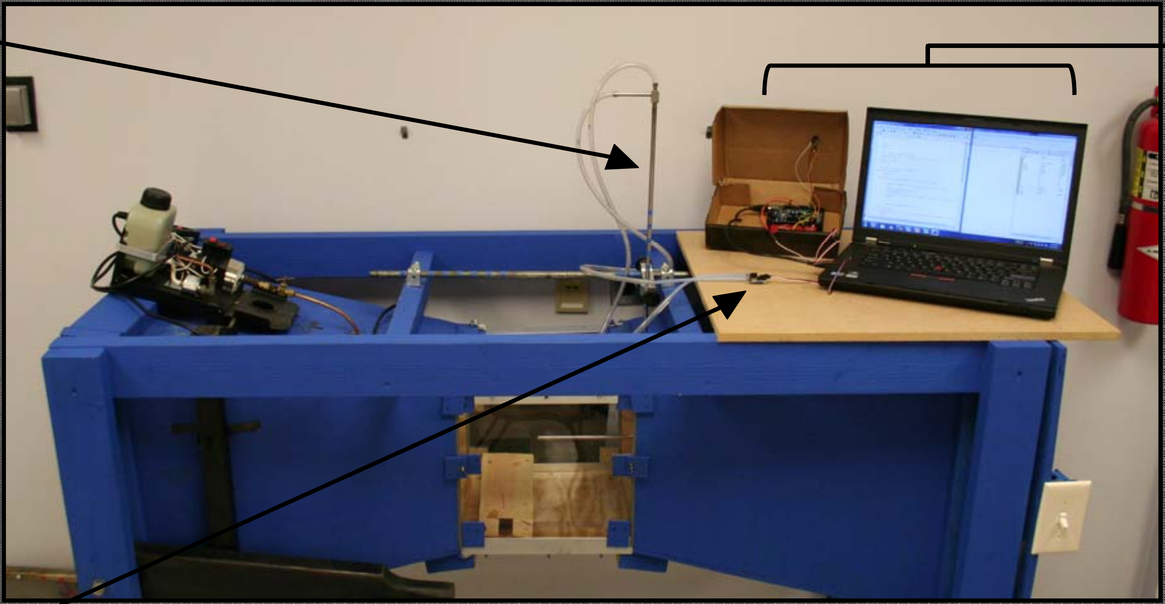


II. Pressure Sensor

To measure this pressure difference we use a differential pressure sensor, seen in the picture above. The sensor takes in the stagnation and static pressure readings separately, and outputs the difference, or dynamic pressure. The wind tunnel has a small maximum air velocity. With the use of Bernoulli's equation, we determined that a +/- 2kPa sensor is the best fit for the wind tunnel. This sensor has an accuracy of at least +/- 130 Pa at a resolution of 5 Pa.

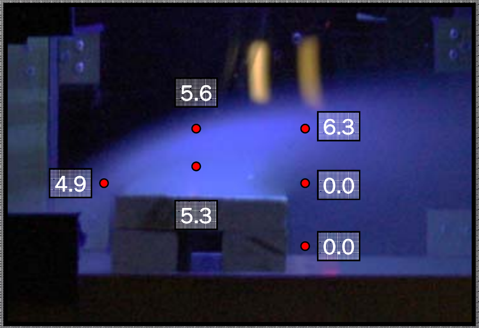
Introduction

Wind tunnels are used to model how air will flow around objects. This information is vital in product design. For instance, if a car is more aerodynamic, then it will require less fuel to travel a distance or if you wanted to design a new wing for a plane, the characteristics of air flow around the wing determine if it flies or not. Research-grade wind tunnels are expensive to run and even more expensive to rent out. The Engineering Department previously sponsored the construction of a small scale wind tunnel through a student project. Their finished design could qualitatively model the airflow, but lacked sensors to gather quantitative data. The goal of this project was to design and implement a system to measure and record the air velocity around objects in the wind tunnel.



Results

Shown at the right is a model of air flow over a backwards-facing step. The red dots show velocities (in m/s) at different points around the step. As the air gets closer to the step, the velocity decreases. Also, the air flow widens as distance from the block increases. However, the data was not conclusive. While our data acquisition setup provides good data to show the general trend of the flow-field, the pitot static tube is too big, the pressure sensor too inaccurate, the wind tunnel test section (12'' X 12'' X 12'') too small, and the low speed fan too slow to produce high quality results. For our tests, we reduced the error and variation in our readings as much as possible by calibrating the pressure sensor and averaging readings at all points of interest over 15-30 seconds.



III. Data Acquisition

For ease of use and automation, we chose the MATLAB computer software as the method to manipulate our dynamic pressure values. By modeling Bernoulli's equation in MATLAB and connecting the pressure sensor to MATLAB through an Arduino micro processor, the data collected by the pressure sensor is converted into velocity measurements instantly. Thus, using MATLAB, the Arduino micro-processor, the Phidgets pressure sensor, and a pitot static tube, we designed a data acquisition framework for our experiment.

IV. Proof of Concept

To prove that our experimental setup is accurate, we tested our setup in a moving car. Holding the pitot tube out of the window of a moving car, we measured air velocity at different speeds and compared them to the speedometer value. As shown in the table below, the two were in reasonably close agreement, considering the effect of wind and other outside factors.

Speedometer	Pitot Tube
40 mph	36.0 mph
50 mph	53.0 mph
65 mph	71.0 mph