Automation of Airflow Mapping System using Pitot-static Principle

B.Sc. (Honours) in Industrial Physics

Department of Physical Sciences

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Project Background

Pitot-static Principle

The Pitot-static tube is a widely used device in today's world and is a common component in gas and air flow measurements. It is named after Henri Pitot. It is commonly used in aerospace and in aerodynamic wind tunnels, where velocity measurements are used in aeroplanes and in space.

The Pitot tube is a valuable method for airflow measurements and is an economical asset to install. The device is comprised of an L-shaped tube with an open end directly facing the airflow.

It is governed by the Bernoulli equation:
$V = \sqrt{\frac{2(P_{stagnant} - P_{static})}{\rho_{air}}}$, where V is the velocity of the airflow, P is the stagnant and static pressure, and ρ is the density of air.

Laminar vs Turbulent Flow
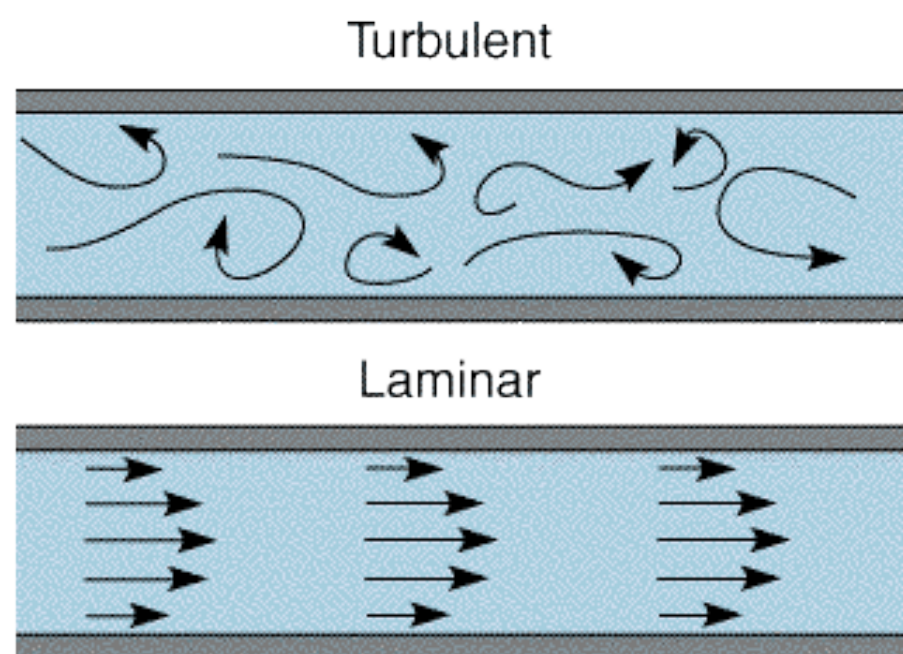
This image depicts the difference between laminar and turbulent airflow. The curve of laminar flow is parabolic in nature, with peak velocity reached in the middle of the pipe. Turbulent airflow introduces spiralling currents known as Eddys. It can be caused by friction between the air and the pipe wall, by thermal properties, and also wind shears along the pipe.
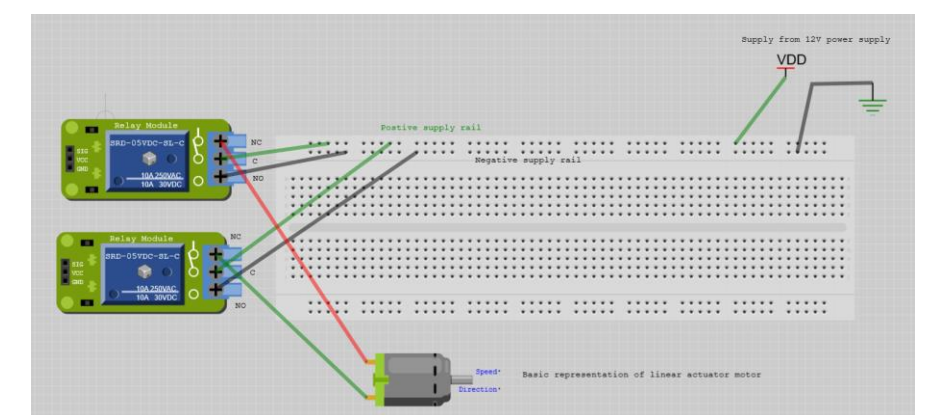
Heat Loss in a Pipe
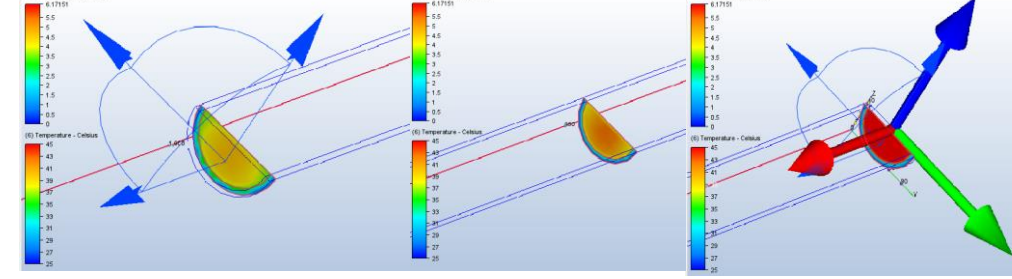
Temperature decreases from right to left (same as pictures). A homemade pipe and fan system (part B of project) was constructed to measure the heat loss down the pipe. 16 holes were made along the pipe, to insert a thermocouple. With ambient temperatures of around 20℃, heat loss is interesting to study as not only the velocity is affected, but other factors come into play. A computational fluid dynamic (CFD) system was used to map this. Comparing cooler airflow to warmer airflow was interesting and was conclusive.

Circuit Design
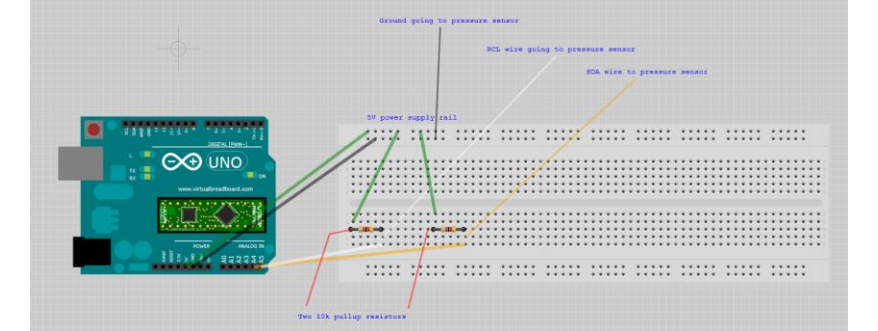
Circuit design was essential for this project. The differential pressure sensor has an I²C bus connection, which required pullup resistors.

The actuator required a 12V power supply, which could then be controlled by the Arduino via a relay module.

Project Design and Experimental Methods

Project Parts A and B

The project was split into 2 parts. Part A focused on obtaining airflow velocities and the main Arduino code. While part B focused on modelling the heat loss in the homemade pipe and fan system.
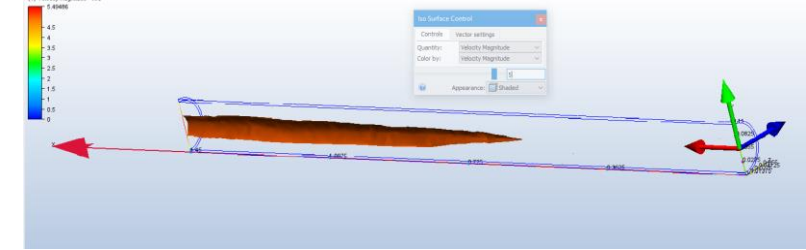
Part A   Part B

Programming

The Arduino was programmed to extend to its next point of measurement, acquire 10 data points, and output the average value of the data points. The Arduino language is similar to C and C++, which I'm sure some people are familiar with. The code became more advanced and concise as the project progressed, outperforming older code.

Simulations

The CFD system was used to simulate the velocity inside the pipe of the main system borrowed from MTU (part A of project). As mentioned briefly in the laminar vs turbulent airflow paragraph, the maximum airflow is generally found in the centre. Lower magnitudes of velocity can be found in the other regions of the pipe. The red area indicates the most likely area to find higher velocity air speeds. The airflow is moving from right to left, as indicated by the arrows.

Hardware Used

The equipment required for this project was either provided by the college or ordered from Radionics online. The Arduino is the main power source and data reader. It is coupled with a 4 double pole relay shield to control the 12V linear actuator, since the Arduino is limited to a 5V maximum output.

The main component is the pressure sensor. It has a range of ±0.1kPa, which is a very suitable range. It is made specifically for the Arduino, so powering it is easy.

Conclusions and Recommendations

User Interface

The GUI was created using Microsoft's VisualBasic program. The simple setup allows the user to connect to the desired communications port and output data on the screen. The Arduino does all the relevant calculations, so the VB.net program is simply displaying the velocities and average velocity values.
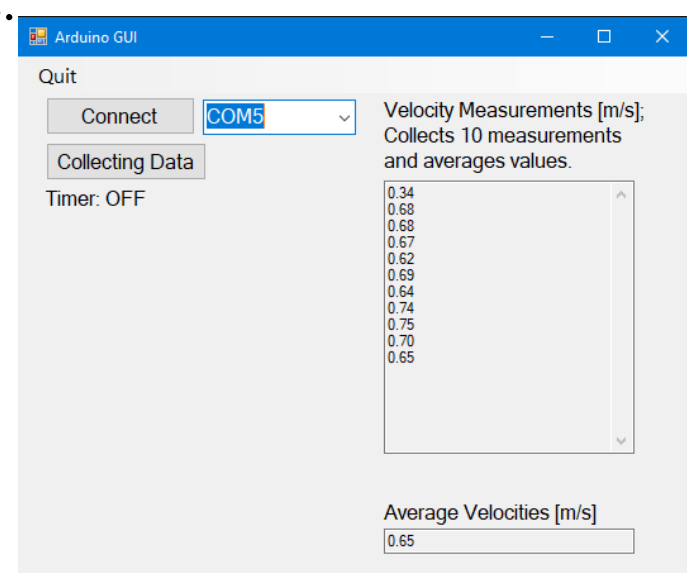
Review of Code and Simulations

The simulations using CFD software proved worthwhile and very beneficial as it can be compared to practical experiments carried out. It does require that the user can 3D model objects in a CAD environment first, but is well worth investing time in it.

As for the coding, lots of time was invested into this with little knowledge prior to beginning. Many tutorials can be found online as Arduinos are widely used for small automation projects. As the weeks went by, the code became more advanced and concise as a direct result from researching.

Conclusions

The project goals consisted of automating the Pitot-static system in order to make it more accessible to future final year students. The Arduino code performs all relevant calculations for the user and steps the actuator each time it is prompted by the user. The VB.net GUI layout is simple and contains relatively simplistic coding. It prompts the Arduino to move the actuator and to obtain the required amount of data points. The points are subsequently printed in a textbox, making the data visible to the user. The data can be copy and pasted into Excel to perform further analysis. The main objective was met in that the code performs the electrical work and also reads the data while performing calculations.

Recommendations

More consideration when selecting a linear actuator should be considered. Actuators with linear feedback are available and would save time. With a built-in potentiometer, the internal circuit board can store values that correspond to the displacement of the actuator arm when it extends and retracts.

Have a basic understanding of circuits and how they work. For example, the circuits used here are important as the sensor would not work without a pair of pullup resistors.

Carry out experimental research as soon as it can be done. Data takes time to render and plot, so this will save time in the long run.

References and Acknowledgements

Laminar vs Turbulent Image: TeachMePhysiology

Heat Loss Images: AutoDesk CFD 2021

Circuit Board Images: Virtual Breadboard app

Data Image: Excel

Code Images: Arduino IDE

Airflow Simulation Image: AutoDesk CFD 2021

Pressure Sensor image: rs-online

GUI Image: VisualBasic

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