Experiment title – Lab 8 –Wind tunnel

Week no. – 8

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Group name – T6

Group members – Jasnoor Tiwana (B21194), Saransh Duharia (B21021), Adarsh Santoria (B21176), Rawal Ram(B21219), Binduthraya Matta (B21203).

1. Experiment layout

In this lab experiment, we investigate the principles of airflow using a wind tunnel. A wind tunnel is a controlled environment that allows us to observe and measure the effects of air flowing around an object. By studying the behavior of air in a wind tunnel, we can gain valuable insights into the aerodynamic forces that act on aircraft, automobiles, and other structures.

Concepts Involved

1. Atmospheric Pressure: Atmospheric pressure is the force exerted by the weight of the atmosphere on the Earth's surface. It is typically measured in units of pascals (Pa) or kilopascals (kPa).
2. Airflow: Airflow is the movement of air from one area to another. The speed and direction of airflow are influenced by various factors, including pressure differences, temperature gradients, and the presence of obstacles.
3. Bernoulli's Principle: Bernoulli's principle states that the total mechanical energy of an ideal fluid element remains constant along a streamline. This principle has important implications for aerodynamics, as it explains the relationship between airflow velocity and pressure.
4. Pitot Tube: A Pitot tube is a device used to measure fluid velocity, typically in air or water. It consists of two tubes, one open at the end and the other facing the oncoming fluid. The difference in pressure between the two tubes is used to calculate the fluid velocity.
5. Engineering Flow Straightener: An engineering flow straightener is a device used to improve the uniformity of airflow. It is typically placed upstream of a sensor or measurement device to ensure accurate and reliable readings. This was basically a bunch of straws stuck together to give us steady flow.

Learning Outcomes

By the end of this lab experiment, we were able to:

1. Explain the concept of atmospheric pressure
2. Understand Bernoulli's principle and its application to aerodynamics.
3. Operate a wind tunnel and use it to measure air velocity using a Pitot tube.
4. Recognize the importance of engineering flow straighteners in achieving accurate and reliable airflow measurements.

2. Results

Task 1 - For the first task, assume we do not have a sensor yet. The goal is to find a differential pressure sensor that enables to measure the wind speed up to 10 m/s using the Pitot-static tube. On that basis, find an analog sensor with the output in Volts. Describe in the report the key features of the sensor. Show a detailed feasibility analysis (etc. calculations) how your selected sensor is suitable for the task and what would be the key specs if applied to a wind tunnel (e.g. min./max. windspeed detectable etc.)

We've chosen the Honeywell Pressure Sensor (NSCDANN150PAUNV) for wind speed measurement, offering a 150 Pascal pressure range suitable for wind speeds up to 10 m/s, with key features including a reasonable differential pressure range, high precision, sensitivity, and a wide operational temperature range.

Feasibility Analysis:

Using the formula ΔP = 0.5 * ρ * V^2, we calculate a maximum pressure difference of 61.25 Pa, confirming the sensor's capability to accurately measure within the specified wind speed range.

Specifications for Wind Tunnel:

- Minimum Detectable Wind Speed: Specify the sensor's lower limit for reliable detection.
- Maximum Detectable Wind Speed: Define the upper limit within which the sensor maintains accuracy.
- Accuracy: Detail the sensor's precision in measuring wind speed differentials.
- Temperature Range: Highlight the operational temperature range for diverse environmental conditions.
- This ensures the effective integration of the Honeywell Pressure Sensor into our wind tunnel application.

Task 2 - Analyze the function of a flow straightener. Connect the pressure sensor to the two pressure tubes, so that you can measure the difference between stagnation and static pressure. Which tube measures stagnation pressure and which tube measures static pressure? Place the tubes at least five different vertical locations and create a vertical flow field map with and without the flow straightener. Logistic details: In the lab there are four wind tunnels with and four without flow straightener. You may club with another group and exchange two types of wind tunnel.

In this experiment without the flow straightener, we observed variations in pressure differences between stagnation and static pressure at different vertical heights.

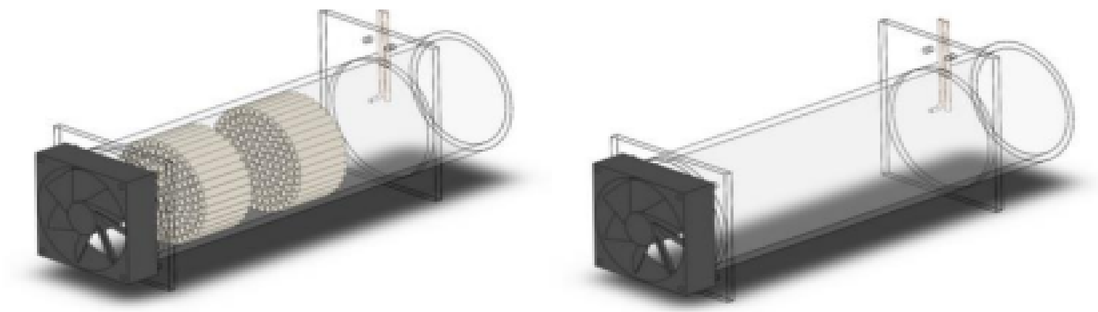
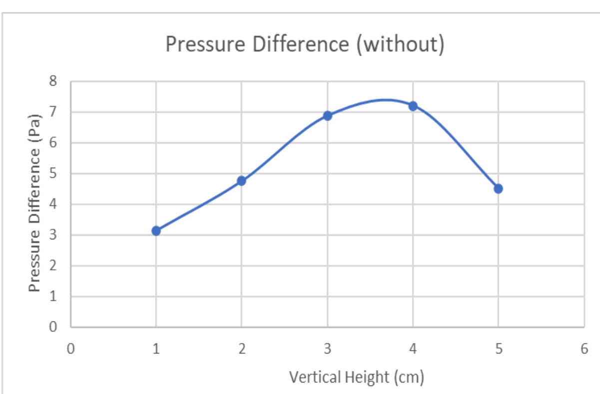


Figure 1: 3D model of wind tunnel with (left) and without (right) flow straightener

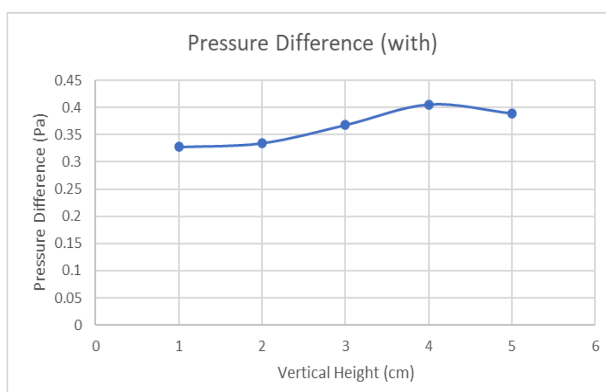
Readings taken with and without flow straightener -

Vertical Height	Pressure Difference (without)	Pressure Difference (with)
3 cm	3.1432	0.3276
4 cm	4.7546	0.3346
5 cm	6.8751	0.3679
6 cm	7.2045	0.4056
7 cm	4.5084	0.3892

The maximum pressure difference occurred at a height of 5 to 6 cm, with readings of 6.8751 Pa and 7.2045 Pa, respectively. These variations suggest that turbulence or uneven airflow impacted the measurements, leading to noticeable peaks in pressure differences. Conversely, in the case with the flow straightener, we noticed a consistent pressure difference at various vertical heights. The readings at 5 cm and 6 cm heights were 0.3679 and 0.4056, respectively. The flow straightener demonstrated its effectiveness by mitigating turbulence and maintaining a more uniform flow field, resulting in nearly constant pressure differences. We can observe this with the help of following plots -



without flow straightener



with flow straightener

Comparing both cases, the flow straightener played a crucial role in achieving more stable pressure readings. Without it, the experiment showed significant variations, particularly at 5 to 6 cm heights. The flow straightener addressed this issue, creating a more consistent airflow and reinforcing its importance in obtaining reliable and stable pressure readings for accurate wind speed measurements.

Task 3 - Determine the power efficiency for both types of wind tunnel. Measure the input power vs. the wind speed using two vertical points. Determine the point of maximum efficiency. The maximum voltage supply on the fans is 7 V.

In our assessment, we measured input power versus wind speed at two vertical points for both wind tunnel configurations—with and without the flow straightener. We calculated power efficiency using the formula PowerEfficiency = ElectricalPowerInput / MechanicalPowerOutput and factored in the maximum fan voltage supply of 7 V. Formulas used -

Efficiency = (Output Power / Input Power) * 100%

Input Power = Voltage * Current

Output Power = (Density * (Velocity)^3)/2

Without flow straightener :

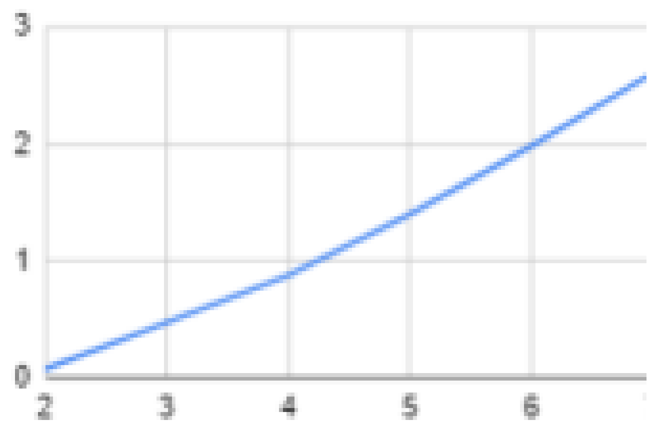
Length	Velocity	Output Power	Efficiency
2.5	1.91	8.3614452	1.793948252
3.5	2.403	16.65108579	0.9008421545
4.5	1.04	1.3498368	11.11245448
5.5	2.99	32.0770788	0.4676236291
6.5	3.23	40.4379204	0.3709389566

With flow straightener :

Length	Velocity	Output Power	Efficiency
2.5	0.519	0.1677580308	89.41449735
3.5	0.47	0.1245876	84.3972145
4.5	0.52	0.1687296	88.89963587
5.5	0.63	0.3000564	49.99060177

In our evaluation, efficiency varied with height, reaching a peak of 11.11% at 4.5 cm and dropping to 0.467% at 5.5 cm without the flow straightener . The maximum efficiency correlated with the height of maximal pressure difference whereas with the flow straightener, efficiency remained stable across heights, ranging from 49.99% to 89.4%, thanks to a consistent pressure difference.

The graph below depicting input power versus fan speed illustrated a continuous increase, emphasizing their direct relationship.



In conclusion, the presence of a flow straightener significantly stabilized power efficiency, ensuring a consistent performance across different heights. The observed variations without the flow straightener underscore the importance of flow management devices in optimizing power efficiency for effective wind tunnel operations.

3. Conclusion

1. **What in your opinion is the most important thing you learnt from the experiment?**

In this experiment, we found out how the wind flows in a tube, with varying pressures and speed of the wind at different distances in the tube from the edges. We also learnt the function of the flow straightener used in the wind tunnels, and that it decreases the value of the dynamic pressure and leads to a more uniform flow profile.

2. **What was interesting about the experiment?**

It was interesting to see how sensors can be used in a wind tunnel to measure various parameters like stagnant and static pressure and get a rough idea about the flow profile of the wind in the tunnel. We were also able to compare the difference a flow straightener can produce in the pressure and velocity of the wind at various levels in the tunnel.

3. **What was challenging about the experiment?**

There weren’t any major roadblocks in the experiment. Although, task 1 was a bit tricky where we had to select the appropriate sensor for this experiment.

4. **Were there any drawbacks of the way the experiment was done? How would you do it better?**

The experiment went pretty smoothly and there weren’t any major drawbacks we faced during the experiment. The only issue was that even with the flow straightener, the fluctuations were still present.

This might have happened due to restrictions in the sensitivity of the sensor, the placement of the flow straightener or the width of the honeycomb in the flow straightener. The issue can easily be resolved by taking a good care of all the above mentioned points, and choosing a better sensor depending on the requirements of the experiment.

5. **Contribution statement** – Adarsh took on the task of coding of the raspberry Pi for plots and tabulating observed readings. Saransh and Jasnoor worked on making the connections for the tasks and observed and relayed the readings to Adarsh. As for the lab report, Saransh focussed on writing the introduction, Adarsh and Jasnoor on presenting the results of the tasks and all three of us worked on the Conclusion part.