Creating Uniform Wind

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Abstract

The main objective of this project is to synthesize a uniform wind. One of the instruments used to develop a uniform wind is called a wind tunnel. The bulk of the work put into this experiment went into the creation of a wind tunnel. After the wind tunnel was built, tests were run on the test chamber to measure the maximum wind speed at eighteen different points. The grid inside the test chamber covered most of its area and from this, results were taken and analyzed. The results for the wind speed were not as uniform as they could have been. The explanation for these less than perfect results ranges from lack of accurate measurement instrumentation to possible construction error. While the results are disappointing there is visually stimulating video of the semi uniform flow.

Introduction

Physicists are people who ask questions and dedicate their lives to the pursuit of the answer. What is man's fascination with flight? Is it the freedom of being thrown into the wind with nothing but the air around you? Perhaps it's the exhilaration or adrenaline rush that you might feel in free fall. Whatever the answer flying and dominion over the skies has been a known topic of conversation for over 500 hundred years ever since the days of Sir Isaac Newton and Leonardo da Vinci. The great minds of the past realized that in order to make these dreams of manned flight a reality there would need to be some experimentation to start with.

This idea of modeling an object in wind is where the idea for creating a wind tunnel comes from. To study the lift and drag forces on objects such as airfoil in wind one requires a steady uniform wind. The first crack at this type of instrumentation came from a man named Benjamin Robins who around the 1700's, "was the first to employ a whirling arm. His first machine had an arm 4 feet long. Spun by a falling weight acting on a pulley and spindle arrangement, the arm tip reached velocities of only a few feet per second." (Baals, Corliss)This revolutionary device started the aeronautic decent into synthetic wind and how to create it. Wind tunnels came about around two hundred years later with the Wright brothers and their success at Kitty Hawk.

The question driving this capstone experiment is what it takes to make a uniform wind flow. The answer is blood, sweat, tears, power tools and about three hundred dollars. The wind tunnel that was made from scratch to create this uniform wind was supposed to yield a uniform wind by pulling air from one side of the tunnel through to the other. There are five main parts to this wind tunnel: the contraction cone, the honeycomb, the test chamber, the diffuser and the fan. They are placed in that order with the honeycomb lying inside the test chamber.

The reason for using this design is because it was simpler to make and a lot cheaper. The wind tunnel has a square test chamber instead of the more popular cylinder test chamber because it is easier to build cubes using a cheaper material such as plywood then it would be to have a molding created with harder plastic. The handheld anemometer, device that measures wind speed and temperature, used in the experiment had a five percent error and was not as accurate as one might hope. Also it was not the correct type of anemometer usually used for wind tunnel measurements. The more popular anemometer being the hot-wire anemometer because it is more accurate and easier to manipulate inside the chamber. These hot wire anemometers go for around one hundred to two hundred dollars while the handheld anemometer was only around seventeen dollars.

Methods

The method used to create this uniform wind was based on two aspects of business theory. The first was money because this severely limited the extravagance of what could be built. On a budget of around two hundred dollars the plywood alone cost almost seventy-five dollars. The honeycomb shape used to straighten the flow was by itself was one hundred and twenty dollars. So already the problem with budget is evident. The time constraint was the other issue because although two semesters of school may seem like a lot of time to do build a wind tunnel, it is not. With school and tests and everything the only time to really get serious about building was during the breaks so that leaves about a month over winter break.

Getting the dimensions correct from the edge of the contraction cone to the edge of the test chamber was by far the biggest sacrifice to performance that had to be made. The angle needed for a contraction cone to be useful is about ten degrees out from the plane of the test chamber. With the dimensions that were used, ten-inch square diameter to a twenty-inch square diameter, the contraction cone would have to have been a lot longer than it is currently. That simply would not have been cost efficient or plausible to move around so to counter that inefficiency a honeycomb pattern ten by ten inch aluminum-straightening device was made. The cells are each one by one inch in diameter and six inches long. This ratio of length to diameter for the cells was determined through this passage, " The lateral components of mean velocity and of the larger turbulent eddies can be reduced more effectively by a honeycomb: the mode of action of a honeycomb with cells elongated in the flow direction is qualitatively obvious but few tests have actually been made, and all that is certain is that the cell length of the honeycomb should be at least six or eight times the cell diameter."(Mehta, Bradshaw)

Another important aspect of the wind tunnel that had to be sacrificed was the fan. For modern wind tunnels it is best to suck the air through the tunnel instead of blowing it through. For budgeting purposes a twenty-dollar room fan was purchased and installed into the back of the diffusion cone. The fan is almost twenty inches in diameter and a perfect fit to the wind tunnel. It has three speeds but for data taking purposes and time the highest speed was the only one tested. A suitable fan for the experiment, but for future work a higher intensity fan might be appropriate.

To view the test chamber from the outside of it a plastic pane was inserted in place of an entire panel for the roof of the test chamber. This see through plastic is then clamped down with a board with a hole cut out of the middle so that visually one is still able to see inside the test chamber. This opening is also where one is able to manipulate whatever goes into the test chamber and where one can see the visual effects of the wind or other fluid, such as fog, on the object placed within the chamber. The four latches that clamp down the wooden window also seal off the wind tunnel so without it closed the wind tunnel will not operate correctly.

Results

The data taken for the maximum wind speed within the test chamber at first glance yielded unfriendly results. From the data it seemed as if the air moving across the top of the chamber were moving slightly more quickly than the air on the bottom of the chamber. There are nine points along the upper half of the wind tunnel test chamber and nine points along the lower half. The average wind speed in the upper half of the test chamber is 4.174 meters per second with a standard deviation of .1164 while the lower half yielded an average of 4.063 meters per second with a standard deviation of .1172.The average wind speed in the entire chamber was 4.119 meters per second with a standard deviation of .1269.

The precision of the measurements between the three runs was very consistent. The majority of the time the maximum wind speed remained the same for all three runs. However on the bottom part of the test chamber the measurements that were taken were slightly less precise then on the top; being off by a tenth of a meter per second in all cases when there was a difference. Overall the anemometer used for the experiment was very useful even though it had a five percent error.

One reason that might have made the difference in the top and bottom of the wind tunnel might have been in the way the measurements were taken. The bulkiness of the handheld anemometer made taking readings very difficult so for taking readings from the top of the test chamber the anemometer was suspended upside down on a rigid metal bar. The readings for the top of the chamber are probably more accurate because nothing was holding around the middle to disturb or meddle with the wind flow. For the bottom part of the test chamber a clamp was used to hold it in place and it was far more intrusive then simply the metal bar. For future research a more suitable anemometer must be used to ensure minimal human error.

Overall the results gained through the handheld anemometer where disappointing but still useful. The precision of the measurements taken is something to be praised because the wind speed may not be as accurate as it should but at least it is consistent.

Discussions and Conclusions

Through statistical analysis, with the help of Dr. Edward Brash, one can say that the differences seen in the wind speed of the wind tunnel are not statistically different. In essence the uniformity of the wind is statistically uniform and therefore a success even though the data my look different. The expectation for the project was to create and test and uniform wind and through countless hours of work that has been achieved successfully. In other words the wind tunnel was a success and may be used in future projects.

The experiment was flawed in many ways from its construction to the taking of the measurements. For future projects to make the wind tunnel that much more uniform one might consider taking the contraction cone and cutting it to the actual measurements that it should be for the ratio that it has and then doing the same for the diffusion cone. The biggest reason for not doing this before was because the wind tunnel was made in northern Virginia and to move something with the exact measurements that it should have been would have been very difficult. Making the enhanced cones would not be difficult because the wind tunnel was made to come apart at the connections for the three main pieces. The three main pieces being the test chamber in the middle and then the two cones at the sides.

As for the measurement method, the reason the results might have been so skewed from the top and bottom might come from the different methods, as mentioned above, that they were taken in. To eliminate this inconsistency one might try buying a better, more expensive anemometer. A hotwire anemometer might work well because it is more accurate than the handheld type and less bulky. The bulkiness of the handheld anemometer is what made taking the data so much more difficult.

All in all the wind tunnel is fully operational and ready for use in perhaps an undergraduate lab. Many schools have pressure labs where the students see the effects of pressure on airfoil and with the wind tunnel Christopher Newport University is that much closer to having one of these labs as well. Further research into this experiment might include creating an undergraduate physics lab.

Appendices

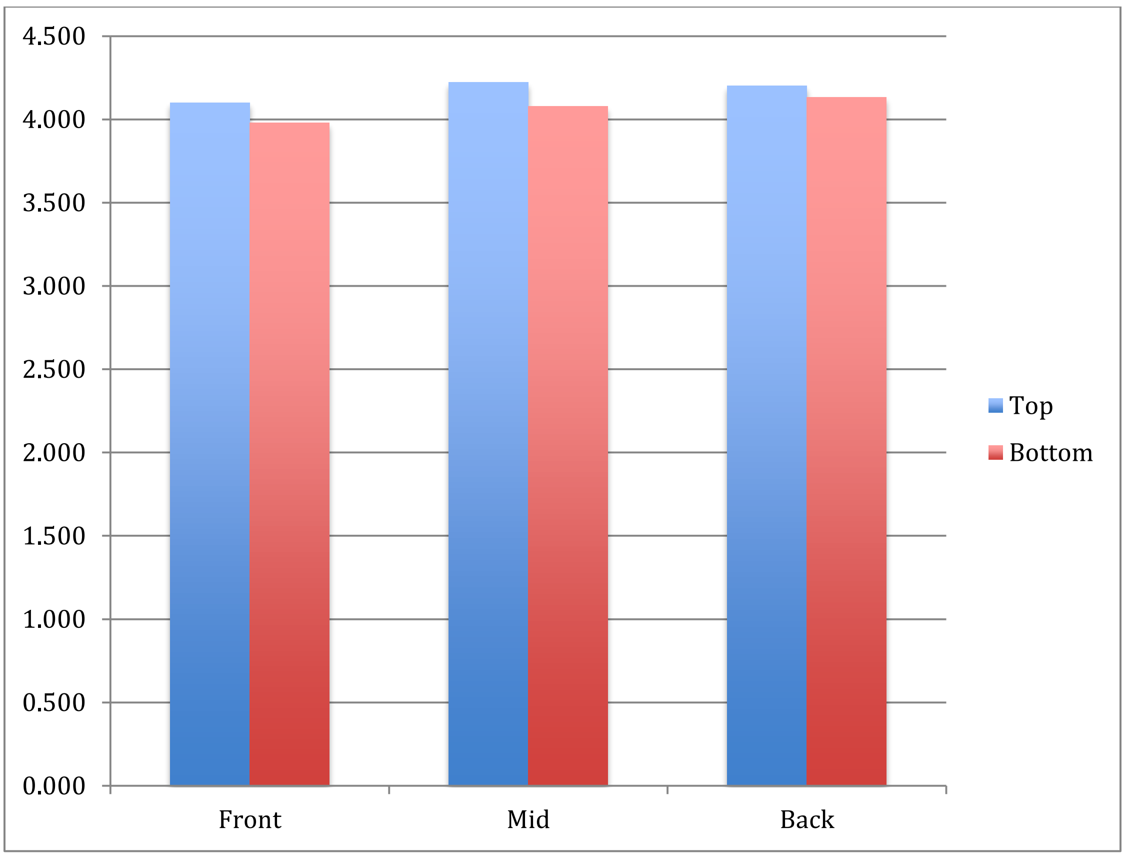
- I could not have made this wind tunnel without the help of my uncle Terry Tracy.
- I utilized his garage, power tools and wisdom to help me create this wind tunnel.
- Chart of raw data

	Top 1 left	Top 1 mid	Top 1 right		
first test	4.1	3.9	4.3		
second test	4.1	3.9	4.3		
third test	4.1	3.9	4.3	**avg top**	std top
average	**4.10**	**3.90**	**4.30**	**4.17**	**0.12**
	Top 2 left	Top 2 mid	Top 2 right		
first test	4.3	4.2	4.2		
second test	4.2	4.2	4.2		
third test	4.3	4.2	4.2		
average	**4.27**	**4.20**	**4.20**	**avg front**	std front
	Top 3 left	Top 3 mid	Top 3 right	**4.04**	**0.17**
first test	4.2	4.2	4.2		
second test	4.2	4.2	4.2	**avg mid**	std mid
third test	4.2	4.2	4.2	**4.15**	**0.09**
average	**4.20**	**4.20**	**4.20**		
	Bot 1 left	Bot 1 mid	Bot 1 right	**avg back**	std back
first test	3.9	4.2	3.8	**4.17**	**0.08**
second test	3.9	4.1	3.9		
third test	4	4.1	3.9	**avg bot**	std bot
average	**3.93**	**4.13**	**3.87**	**4.06**	**0.12**
	Bot 2 left	Bot 2 mid	Bot 2 right		
first test	4.1	4.2	4		
second test	4.1	4.1	4		
third test	4	4.1	4.1		
average	**4.07**	**4.13**	**4.03**		
	Bot 3 left	Bot 3 mid	Bot 3 right		
first test	4.1	4.3	4		

second test	4.1	4.2	4
third test	4.1	4.3	4.1
average	**4.10**	**4.27**	**4.03**

overall avg:	**4.12**
overall std:	**0.13**

- Graph of the data



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