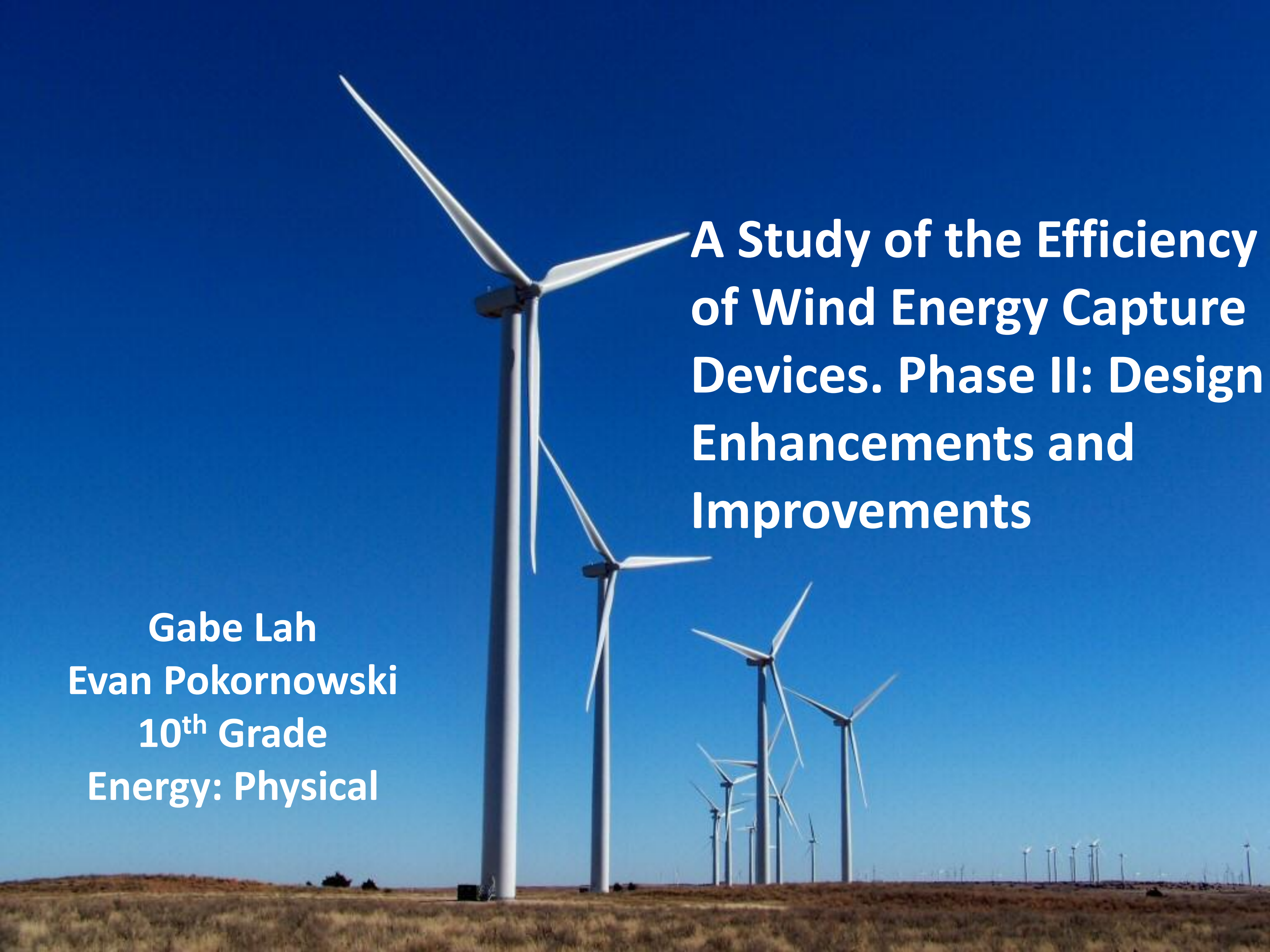

A Study of the Efficiency of Wind Energy Capture Devices. Phase II: Design Enhancements and Improvements

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10th Grade
Energy: Physical

Introduction

- Windmill blades are constantly changing
  – In the past they were insignificant and inefficient in generating clean and renewable energy (Windmill, 2013; Windstuff, 2011)
- The shape of the blades can highly effect the outcome of the energy produced
  – The Maglev (see image)
  – Old windmill
  (Science Daily, 2007)

www.theguardian.com

http://inhabitat.com/sheerwinds-invelox-wind-turbine-can-generate-600-more-energy-than-conventional-turbines/

Introduction

- Wind Power can be a very useful when generating energy
- Using the right propeller design and material is important in order to produce efficient energy
- The latest materials for windmill blades are made from

  - Fiber-glass
  - Epoxy resin
  - Raw materials that make pvc piping

(Force Field, 2010; Wind Turbine, 2011)

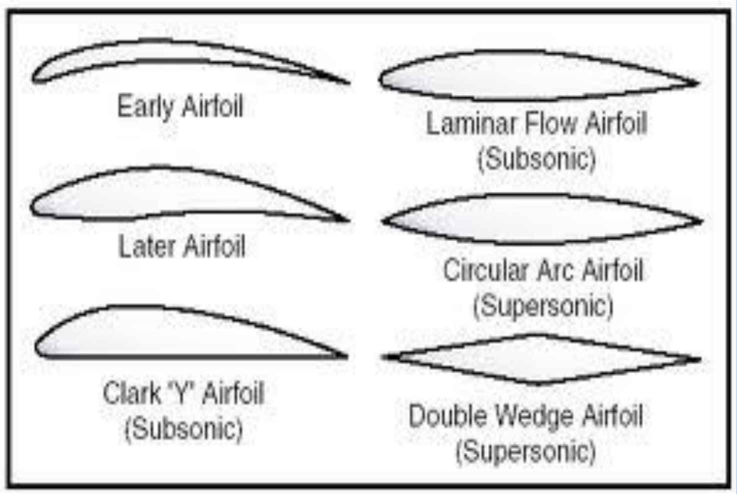
Modern day Air turbine

http://inhabitat.com/sheerwinds-invelox-wind-turbine-can-generate-600-more-energy-than-conventional-turbines/

Introduction

- Turbine blade shape
  - A wind turbine's blade shape is called “airfoil.”
  - The shape of the airfoil
    - Creates high and low pressure areas
    - On opposite sides in order to minimize air turbulence

(Bensen, 2012)



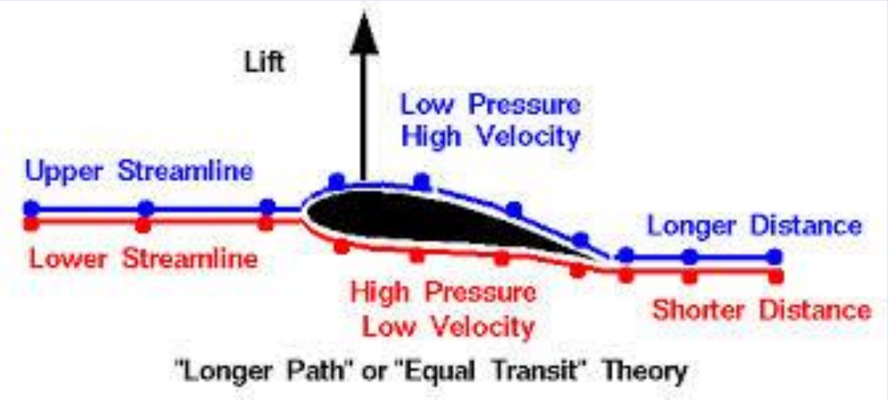
Different kinds of airfoils

http://www.google.com/url?sa=i&rct=j&q=airfoils&source=images&cd=&cad=rja&docid=7B5gR2RiFRr8IM&tbnid=1yPdjXlop_vVPM:&ved=0CAQQjB0&url=http%3A%2F%2Fwww.free-online-private-pilot-ground-school.com%2Faerodynamics.html&ei=4wkVU4LAA46drgGBmYHABw&bvm=bv.62286460,d.aWM&psig=AFQjCNHDljH-hIhJQZZ98GYSCgARQvcPGw&ust=1393974112453317

Introduction

- Lift continues as long as the airfoil is moving through the air
  - Its best if the air remains smooth rather than turbulent
- Turbulence wastes energy by
  - Creating resistance that slows down the rotational speed of each blade decreasing efficiency

  (Bensen, 2012)



http://www.google.com/url?sa=i&rct=j&q=lift%20on%20an%20airfoils&source=images&cd=&cad=rja&docid=0hErfRS0AF_shM&tbnid=TIkTXTccotHLGM:&ved=0CAQQjB0&url=http%3A%2F%2Fen.wikipedia.org%2Fwiki%2FLift_(force)&ei=XgoVU6L6JcGtrgHlooHwDQ&bvm=bv.62286460,d.aWM&psig=AFQjCNE8xZq3VndpJvIO03FpwgHQyWHh7w&ust=1393974221753693

Question/Hypothesis

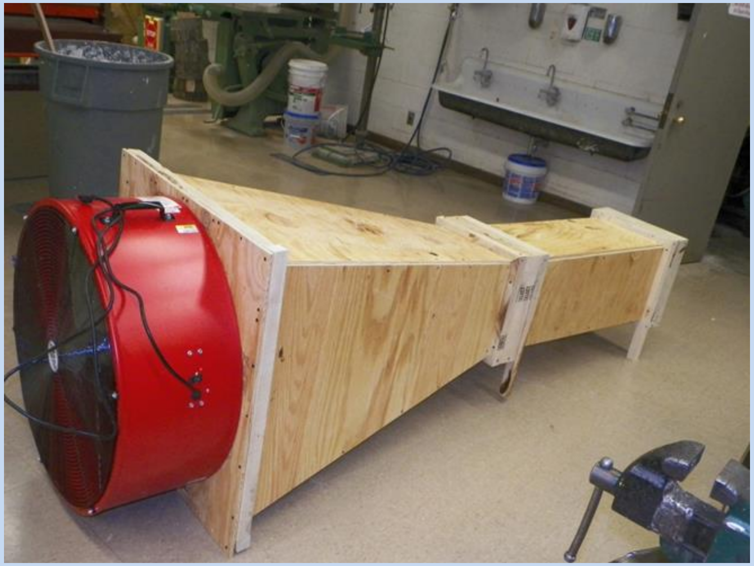
- Engineering Goal: to design and fabricate a PVC wind tunnel capable of laminar flow with diminished turbulence when compared to a plywood design.
- Question: What effect do the materials used to construct a wind tunnel have on laminar flow?
- Hypothesis: If PVC sheets are used instead of plywood, then there will be less turbulence and more laminar flow inside of the wind tunnels testing chamber.

Method

- Independent Variable
  - The fabricated airfoil profiles
  - The material used to design the wind tunnel (PVC vs. plywood)
- Dependent Variable
  - The lift generated
  - The creation of laminar flow
- Constant Variable
  - Speed of the fan
  - The profile positioning inside the testing chamber
  - Airfoil material The use of a designed and fabricated wind tunnel

Method

- The following procedure was used to conduct this experiment:
- A wind tunnel was designed and fabricated in a indusial technology shop
  - Supervised by an Engineer
  - Student researchers were train in shop safety, safe use of the shop tools, and had safety equipment on at all times
- The new wind tunnel was based off of the design from last year (plywood)
- Made smaller and with PVC sheets instead of plywood

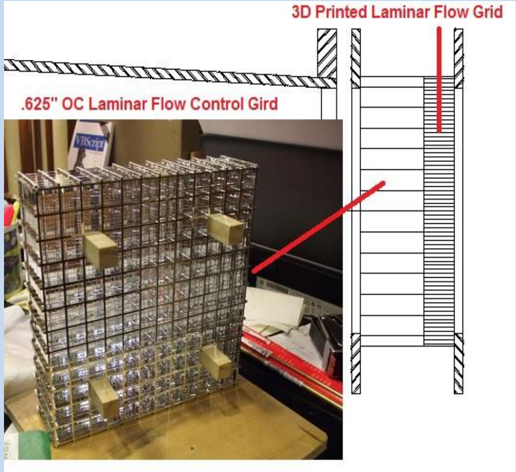


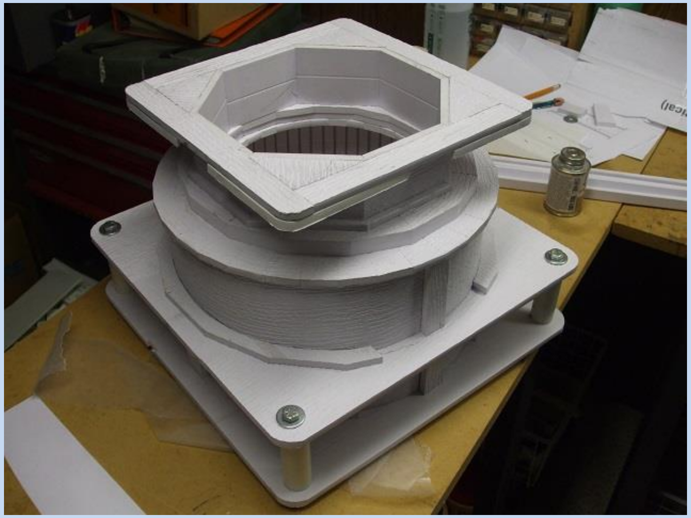
Method

- The first section, the wind tunnel frame was constructed using the following:
  - Six 5/16th inch by 8 foot white vinyl
  - S4S flat vinyl utility trim molding
  - Two 1/8th inch by 12 foot white vinyl outside corner molding
  - One 4 foot by 2 foot suspended light ceiling panel
  - Two sheets of acrylic
  - One roll of masking tape
  - One can of large PVC cement
  - The test bed size was determined by the size of the blades tested (4 inches) and the stand holding the blades

Method

- The second section of the wind tunnel was the setting chambers (flow straightener)
  - This section is right before the testing chamber and before the fan
  - It was constructed from the suspended light ceiling panel
  - The straightener's purpose was to allow the air to only enter in one direction
- The third section was the Contraction Cone
  - Its purpose was to funnel the air flow into the testing chamber straight
  - It was made of many polygons with sides of 32 to 16 to 8 to 4 to funnel the wind before it got to the testing chamber



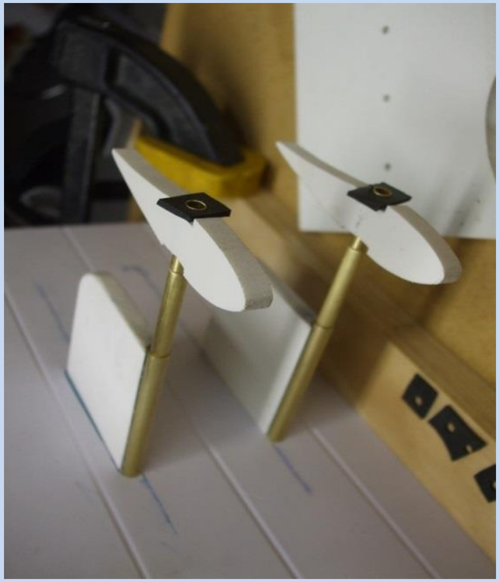


Method

- Fan housing
  - Four blade thirty inch drum fan
  - Controlled by a variable speed motor

Method

- Three four-inch blades were drawn in the CAD design computer program
  - The profiles were fabricated by the student researchers and project coach using an MH1 method
  - Each designs maintained the same surface area
  - Each profile was made out of the same materials
  - The profiles were mounted to the lift measuring mechanism, and placed inside the testing chamber
  - The lift measuring device was made from copper tubing, springs, PVC, and a scale to measure lift



Data Tables

Testing Chamber

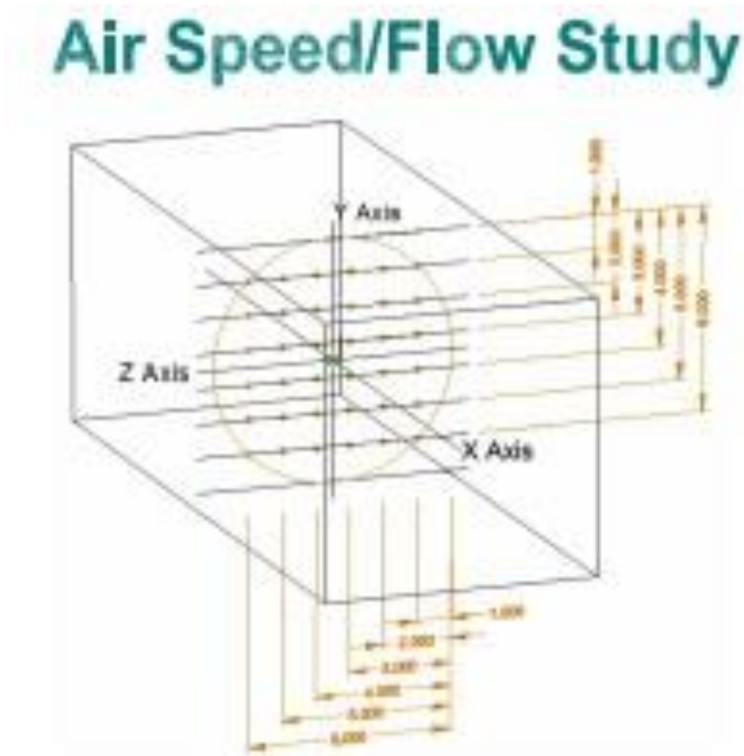


Table 1 and 2: Wind speed grid that indicates velocity across the testing chamber according to the size of the fan (miles per hour)

Data Run: 32" Fan

	1	2	3	4	5	6	Data @ Fan:	
1	12.0	11.5	11.4	12.6	12.1	14.8	04"	2.0
2	14.1	12.0	11.4	12.1	12.7	15.6	08"	1.2
3	14.1	12.0	10.3	10.1	12.2	15.7	12"	1.7
4	14.7	12.4	09.0	08.8		14.5	16"	2.7
5	15.5	11.3	10.6	10.2	11.4	15.6	20"	1.5
6	16.2	15.0	12.8	11.4	12.5	15.6	24"	1.7
							28"	2.2

Data Run: 12" Fan

	1	2	3	4	5	6	Data @ Fan:	
1	14.5	15.5	15.5	16.0	16.6	16.7	1-11/16"	21.8
2	15.3	16.3	16.6	16.7	16.2	18.1	(1-11/16)*2"	19.6
3	16.4	12.0	15.0	15.3	17.3	18.5	(1-11/16)*3"	06.9
4	17.6	16.6	15.9	17.3		18.0	(1-11/16)*4"	02.7
5	17.8	16.8	15.5	17.2	11.4	17.7	(1-11/16)*5"	06.6
6	17.6	17.6	16.0	16.7	12.5	15.8	(1-11/16)*6"	19.6

Table 2: A comparison of wind tunnels and fans (PVC vs. Plywood) and (32 inch vs. 12 inch) by wind velocity (miles per hour)

Dependent Variable: Velocity
LSD

(I) Fantype	(J) Fantype	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
12 inch PVC	32 inch PVC	3.3386*	.45563	.000	2.4327	4.2445
	Plywood 32 inch	12.1086*	.63938	.000	10.8373	13.3798
32 inch PVC	12 inch PVC	-3.3386*	.45563	.000	-4.2445	-2.4327
	Plywood 32 inch	8.7700*	.62847	.000	7.5204	10.0196
Plywood 32 inch	12 inch PVC	-12.1086*	.63938	.000	-13.3798	-10.8373
	32 inch PVC	-8.7700*	.62847	.000	-10.0196	-7.5204

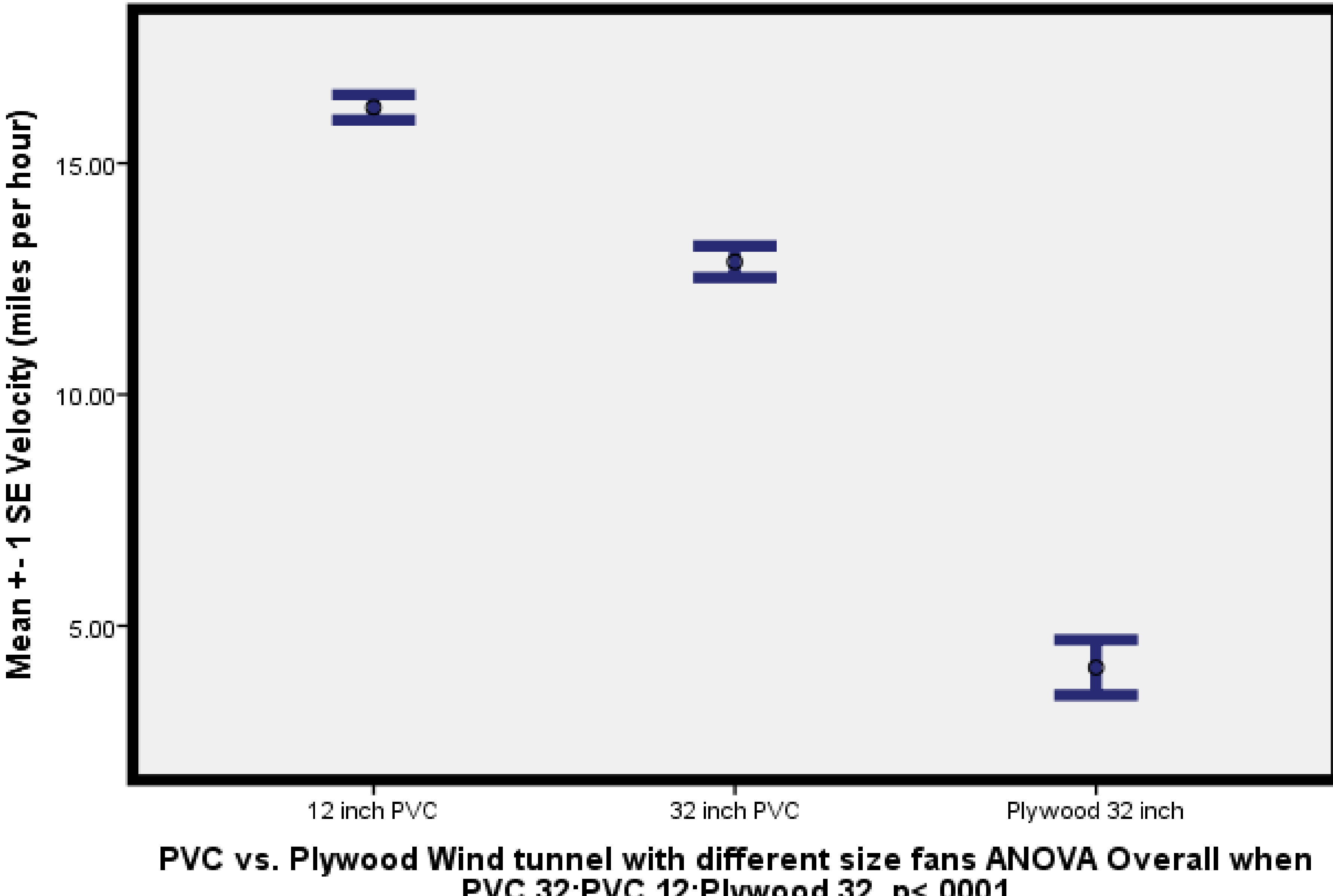
Based on observed means.
The error term is Mean Square(Error) = 3.875.
*. The mean difference is significant at the .05 level.

Table 3: A comparison of wind tunnels and fans (PVC vs. Plywood) and (32 inch vs. 12 inch) by wind velocity (miles per hour)

Dependent Variable: Velocity

LSD	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
12 inch PVC	16.209	.333	15.547	16.870
32 inch PVC	12.870	.311	12.251	13.489
Plywood 32 inch	4.100	.546	3.014	5.186

Figure 1: The average wind velocity in miles per hour when a PVC and Plywood wind tunnel are compared (32 inch vs. 12 inch fan)



Results

- **This study was done to design and fabricate a PVC wind tunnel capable of laminar flow with diminished turbulence when compared to a plywood design.**
  - The 32 inch fan did not generate laminar flow in the wind tunnel
    - Unequal distribution of airflow across the testing chamber
    - Winds speeds ranging from 6.8 to 16.2 miles per hour
    - Back draft was created, there was almost as much air coming out the back of the fan as was going into the wind tunnel
  - The 12 inch fan generated laminar flow in the wind tunnel
    - Increased level of equal distribution of airflow across the testing chamber
    - Wind speeds ranging from 11.2 to 17.6 miles per hour
- Figure 1: The average wind speed (miles per hour) when a wind tunnel is made from PVC board and Plywood using different fan diameters
  - 16.209 ±.333
  - 12.870 ±.311
  - 4.100 ±.546

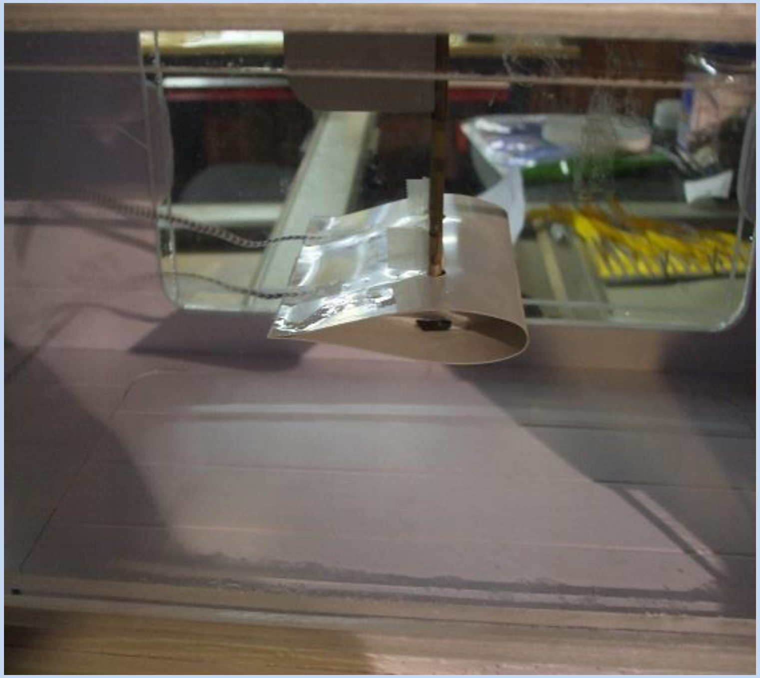
  - Not enough wind was generated to create lift for the profile designs

Conclusion/Discussion

- Engineering Goal: to design and fabricate a PVC wind tunnel capable of laminar flow with diminished turbulence when compared to a plywood design.
  - The goal was partially accomplished when the 12 inch fan was used, laminar flow was created
  - Yet, when the profile blades were tested there was not enough wind velocity for lift

Conclusion

- Hypothesis: If PVC sheets are used instead of plywood, then there will be less turbulence and more laminar flow inside of the wind tunnels testing chamber.
  - Hypothesis was supported
  - The PVC designed wind tunnel had less variability and higher wind speeds on average than the Plywood design, ANOVA $p<.0001$
- Continued testing needs to be done on different blade profiles using a fan that can produce enough wind velocity to generate measurable lift



Conclusion/Discussion

- Next time the student researchers would like to
  - Build a fogging module to see laminar flow
  - Design new airfoil designs
  - Find another fan with higher wind speeds, that can achieve lift in the profiles

http://inhabitat.com/energy-ball-by-home-energy/

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