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)

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)
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)
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)
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 industrial 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)
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

<table>
<thead>
<tr>
<th>(I) Fantity</th>
<th>(J) Fantity</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 inch PVC</td>
<td>32 inch PVC</td>
<td>3.3386</td>
<td>.45563</td>
<td>.000</td>
<td>2.4327 - 4.2445</td>
</tr>
<tr>
<td></td>
<td>Plywood 32 inch</td>
<td>12.1086</td>
<td>.63938</td>
<td>.000</td>
<td>10.8373 - 13.3798</td>
</tr>
<tr>
<td>32 inch PVC</td>
<td>12 inch PVC</td>
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<td>-4.2445 - -2.4327</td>
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<tr>
<td></td>
<td>Plywood 32 inch</td>
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<tr>
<td>Plywood 32 inch</td>
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<td></td>
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<td>-10.0196 - -7.5204</td>
</tr>
</tbody>
</table>

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

<table>
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<tr>
<th>LSD</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 inch PVC</td>
<td>16.209</td>
<td>.333</td>
<td>15.547 - 16.870</td>
</tr>
<tr>
<td>32 inch PVC</td>
<td>12.870</td>
<td>.311</td>
<td>12.251 - 13.489</td>
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<tr>
<td>Plywood 32 inch</td>
<td>4.100</td>
<td>.546</td>
<td>3.014 - 5.186</td>
</tr>
</tbody>
</table>
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)

PVC vs. Plywood Wind tunnel with different size fans ANOVA Overall when PVC 32:PVC 12:Plywood 32, p<.0001
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 ± 3.333
  – 12.870 ± 3.11
  – 4.100 ± 5.46
  – 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/
References


