Wind Turbine Blade Design

Blade design and engineering is one of the most complicated and important aspects of current wind turbine technology. Engineers strive to design blades that extract as much energy from the wind as possible while also being durable, quiet and cheap.

Materials:

- Model turbine that can quickly interchange blades (KidWind turbines are perfect)
- Blade construction materials (cardboard, balsa wood, coroplast, index cards, scissors, glue, tape, etc)
- Multimeter or Voltage/Current Data Logger
- Box fan
- Ruler
- Pictures of wind turbine blades
- Scale model turbines (optional)
- PowerPoint of wind turbines blades (optional)
- Wind speed meter (optional)

Intro Questions for Students

1. Have you ever seen a wind turbine in real life?
2. Why would we want to build wind turbines?
3. How much energy do we get from wind?
4. Where are wind projects built?
5. What variables affect the power output from wind turbines? Push students on this last question to get several answers: wind speed, generators, size of the turbine, gear ratio, blade design.
6. We will now begin exploring blade design of wind turbines.

Blade Variables

What variables affect how much energy the blades can capture? Length, number, pitch/angle, shape, weight, material, curvature, twist, wind speed, etc. Students should break into groups of 2—4 and choose one blade variable to test. Once they have performed regulated experiments on this one variable they should collect data and present their discoveries to the class.

Blade Construction and Testing

Once students have an approved plan they can start to construct and test blades. As they are doing this make sure they are isolating one variable and keeping all others constant. Also make sure students are being safe and collecting meaningful data. When students have constructed a set of blades, mount the blades on the wind turbine and place it in front of the fan. When the blades are spinning the turbine is producing electricity. Use a multimeter to measure voltage. If you have time, also measure current (amps). Remember: Power is equal to voltage times current ($P = IV$). Students sometimes take too much time making blades. It is important to work efficiently as they need to collect data from 3—4 different tests of their isolated variable.

Optional Discussion Idea: Power in the Wind

This is a very important equation in wind energy science: How much power is available in a certain area of wind? If you know the swept area of your turbine blades and the wind speed, you can calculate roughly how much power is theoretically available in the wind.

$$P = 1/2\, \rho\, A\, V^3$$

Power = ½ x air density x blade area x wind

Ask students if the data the class collected reflects the basics of this equation. Based on this formula what is the most important variable? What is the next most important? What variable in the equwation did we not test? What variables did we test that are not expressed in the formula? In this experiment it is common to find that bigger blades do not make much power. This is typically due to the fact that large student-made blades have lots of drag! Drag will slow the blades down dramatically.

Evaluating the Blades

Aside from power output, you can also evaluate blades based on their quality of construction and the aesthetics of the blade design. Have all students display their blades on a desk or table. Spend 10-15 minutes having the students themselves walk around and evaluate the blades. They can rate each one on a 1-5 scale for both quality of construction and aesthetics of the design. You can ask students to predict which blades will be the best and why.

Once the student evaluation is finished, collect their grading sheets and move on to power output testing. You can use students as recorders, timers, and multimeter operators. Let each student mount and set their own blades.

Place the turbine at about one meter away and let it run for 30 seconds. Record data (voltage, amperage, or both). We recommend picking the highest number you see in 30 seconds. Make sure that a student is recording this data. If after a few seconds students want to adjust their blades in the hub let them do it once.

After all students have tested and collected data, you can qualitatively compare blades. If you measured both voltage and amperage you can now calculate power output in watts.

Conclusion/Discussion

It may take a while to tabulate all the data, but once you select the blades that make the most power and are well designed, you can give a small prize to these student engineers. A t-shirt, candy bar, or other small prize is perfect for the blade design champions.

Discussion about blade design can get very deep if you choose to dig in. You may want to touch on lift/drag principles, Bernoulli's principle, the airfoil shape, twisted pitch, number of blades, variable pitch blades, what real turbine blades are made of, tip speed ratio, etc.