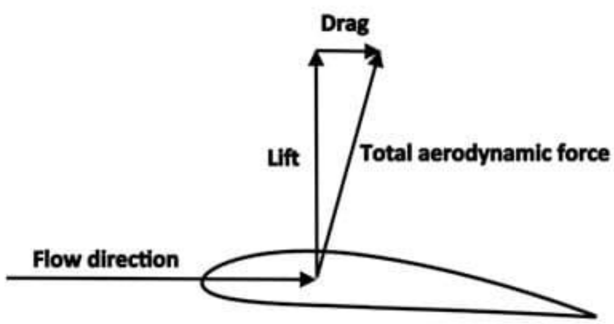
The Science of Turbine Blade Building

KidWind Challenge Teacher Instructions

Turbine Blade Design

Aerodynamics is the way air moves around objects. Aerodynamic behavior explains how birds and airplanes can fly and how race cars are able to travel at extremely high speeds. Any flying object has a meaningful aerodynamic design to enable it stay afloat in the air. Rotor blades on wind turbines have unique and intentional aerodynamic designs as well. Aerodynamic design enables rotor blades to capture most of the wind's kinetic energy. A rotor blade's design is similar to an airplane wing. The same two aerodynamic forces that lift and fly airplanes are at work when wind exerts force against a wind turbine rotor blade. These two forces are known as lift and drag.



Lift is the force that pushes something up. Drag is the force that tries to "drag" or slow down an object. An object's shape dictates the amount of lift and drag that will occur. Round surfaces have less drag than flat ones. Narrow surfaces typically have less drag than wider ones. In general, if more air hits a surface, more drag occurs.

In the case of wind turbine rotor blades, the direction and amount of wind force that is applied against the rotor blades determines the amount of lift and drag that causes the blades to rotate. The stronger the force of wind exerted against the rotor blades, the stronger the lift and the drag, which in turns rotates the wind turbine and generates more electricity.

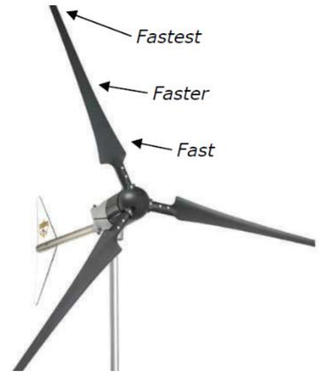
When designing rotor blades, engineers consider the size, aerodynamic shape and number of blades attached to the wind turbine's rotor. These three components dictate how much lift and drag act against the wind turbine's rotor blades. Remember, the use of curves and round surfaces results in better aerodynamic shapes, as seen in the design of aircraft wings, helicopters, kites and sailboats.

Source: Teach Engineering-Renewable Energy Design: Wind Turbines

Encourage students to consider:

1. **Blade Shape:** Drag is a force that acts on an object. The smoother the surface the less the drag. It is a type of friction. Think about Olympic swimmers. They compete in tight, smooth suits to reduce drag. Another factor is that rounded surfaces have less drag that flat ones. Think about a jet wing. The top is curved so it has less drag which helps in lift. If the blades are thinner at the end there will be less drag on the rotor.

2. **Blade Pitch:** Blade pitch control is a feature of nearly all large modern horizontal-axis wind turbines. It is used to adjust the rotation speed and the generated power. While operating, a wind turbine's control system adjusts the blade pitch to keep the rotor speed within operating limits as the wind speed changes. A specifically designed
protractor is included with your kits to accurately measure your blade pitch.



Using a fan, try this experiment to explore pitch:

- Turn on a fan and place your hand in front of it about 5 feet away.
- Extend your arm toward the fan with your palm facing the floor. What happens to your hand?
- Move your hand so your palm is facing the fan. What happens to your hand?
- Now, place your hand in front of the fan at a 45° angle with your thumb facing up and your palm facing the fan. What happens you your hand?
- Finally, place your hand in front of the fan at a 45° angle with your thumb facing down and your palm facing away from the fan. What happens you your hand?
- Experiment with different angles to determine which angle has the best lift.

3. **Blade Length:** Blades that extend beyond the size of the fan do not catch air. The extra weight makes it more difficult for the rotor to spin. Be sure the blades will not touch the ground when attached to the nacelle. Wind turbines with longer blades do make more power. While this is also true on our small turbines it is often difficult for students to make large, long blades that do not add a lot of drag and inefficiency. See what happens when you shorten them a few centimeters.
4. **Number of Blades:** Consider the weight, balance and energy needed to turn the rotor. Heavier blades take more energy to move. The faster your rotor spins, the greater the voltage produce.

Turbine Blade Building Tips

1. To make blades, carve or cut different shapes and sizes out of a variety of materials (wood, cardboard, felt, fabric, plastic) and hot glue or tape them to the dowels. Students have made blades out of styrofoam bowls or plastic cups. Anything you find around the house, classroom or recycling container can be made into blades.

2. Before testing, check that the blades are securely attached to the dowel. If not secured properly, they may detach or deform as you test your turbine in high winds. We recommend using a combination of tape and hot/regular glue.
3. Insert the dowels into holes on the hub. It is important to tighten the hub when inserting the blades so that they do not come out at high speed.
4. When attaching the blades to the hub consider a few important questions.
   - How close is the root of your blade to the hub? What do you think is optimal?
   - Are your blades about the same size and weight? Blades that are not balanced will cause vibrations that can reduce the efficiency of your turbine.
   - Are the blades equally distributed around the hub? If not, you can also have a set up that is out of balance.
   - Have you secured the hub after you inserted the blades? Remember that they may fly out at high speed.