Building Tips, Troubleshooting & Testing

Advanced Design Challenge: KidWind Turbine

Tower Assembly

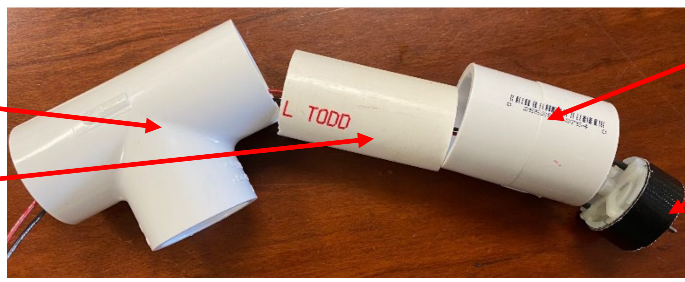
1. Using the KidWind kit, assemble the tower and base with three supports.
2. Wrap a piece of duct tape around the outside of the motor. Tape should be about 1/2” wide and 18” long. This will help the motor fit securely into the PVC coupler.

4. Use the PVC Tee fitting, 3” PVD pipe, PVC coupler. Arrange the pieces as they look in Image #1. Push them together to form a solid piece like Image #2. On a large wind turbine this is called a nacelle. It holds the generator, gear boxes, and other equipment.

Image #1

PVC Tee Fitting

3” PVC pipe

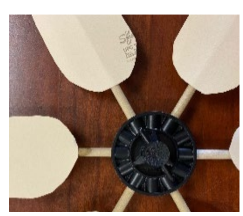


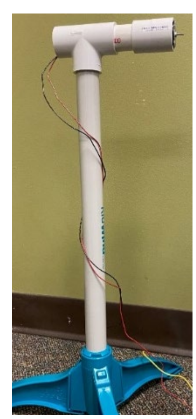
PVC Coupler

Motor

Image #2

5. Insert the wires attached to the DC motor through the nacelle. They should come out of the PVC Tee fitting. (Image #2)
6. Insert the motor into the PVC coupler. It should be straight and fit VERY snuggly. If it is too loose or too tight adjust by wrapping or unwrapping duct tape around the outside. Since the motor is pushed on frequently by students, it must be TIGHT! You can glue this in to make it secure. If the motor looks cockeyed, straighten it out as it will cause your hub and blades to wobble while spinning.
7. Attach the nacelle to the top of the tower.
8. Attach the finished blades, by loosening the top screw of the hub. Insert the dowels with the completed blades. Adjust the pitch, then tighten. Be sure blades are secure to prevent them from flying off when testing.
9. Press the hub onto the driveshaft. It should fit very snuggly.



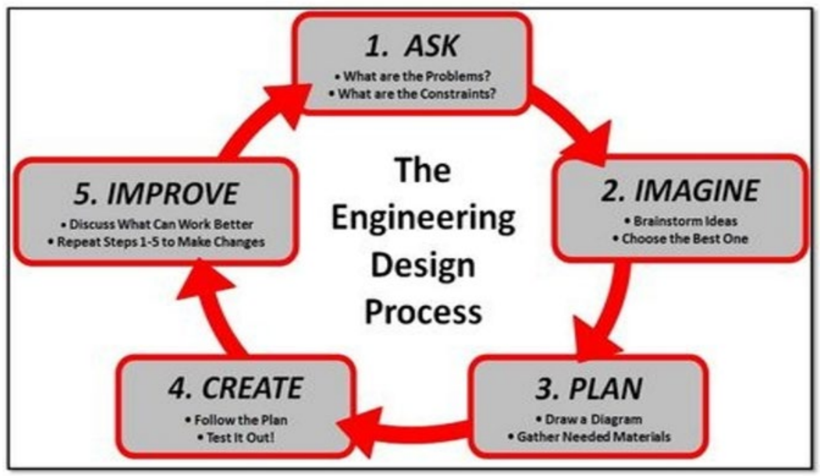


10. Wrap the motor wires around the tower and secure to the base with electrical or duct tape. You can also drill a hole in the base of the tower before assembly. Snake the motor wires down the tower and through the hole in the PVC at the base of the wind turbine.

Introduce the Engineering Process

To have the best success in this activity, you should utilize the engineering design process.

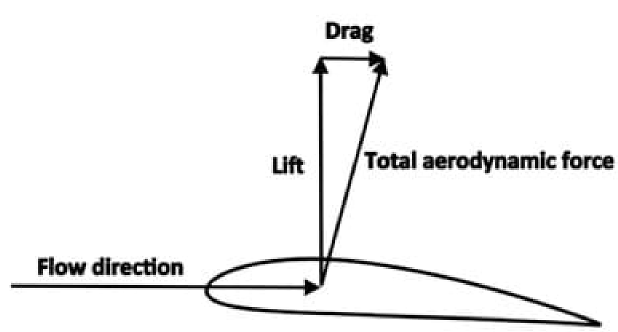
1. **ASK:** What is the problem? What are the constraints?
2. **IMAGINE:** Brainstorm ideas. Think outside the box. Choose the best one.
3. **PLAN:** Draw a diagram. Gather needed materials.
4. **CREATE:** Follow the plan and test your design.
5. **IMPROVE:** Discuss what can work better. REPEAT steps 2 through 5 to make changes.



Turbine Blade Design

Aerodynamics is the way air moves around objects. Aerodynamic behavior explains how birds and airplanes are able to 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.

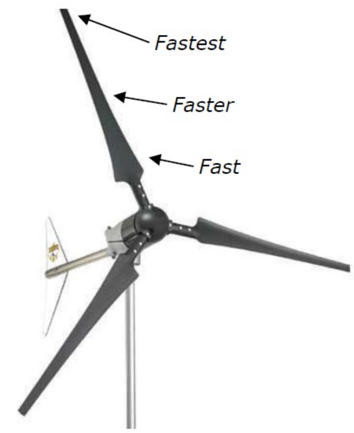
Lift is the force that pushes something up. Drag is the force that tries to "drag" or slow down an object. An object's shape dictates the amount of lift and drag that will occur. Round surfaces have less drag than flat ones. Narrow surfaces typically have less drag than wider ones. In general, if more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



The further away from the center, the faster the blades spin.

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.

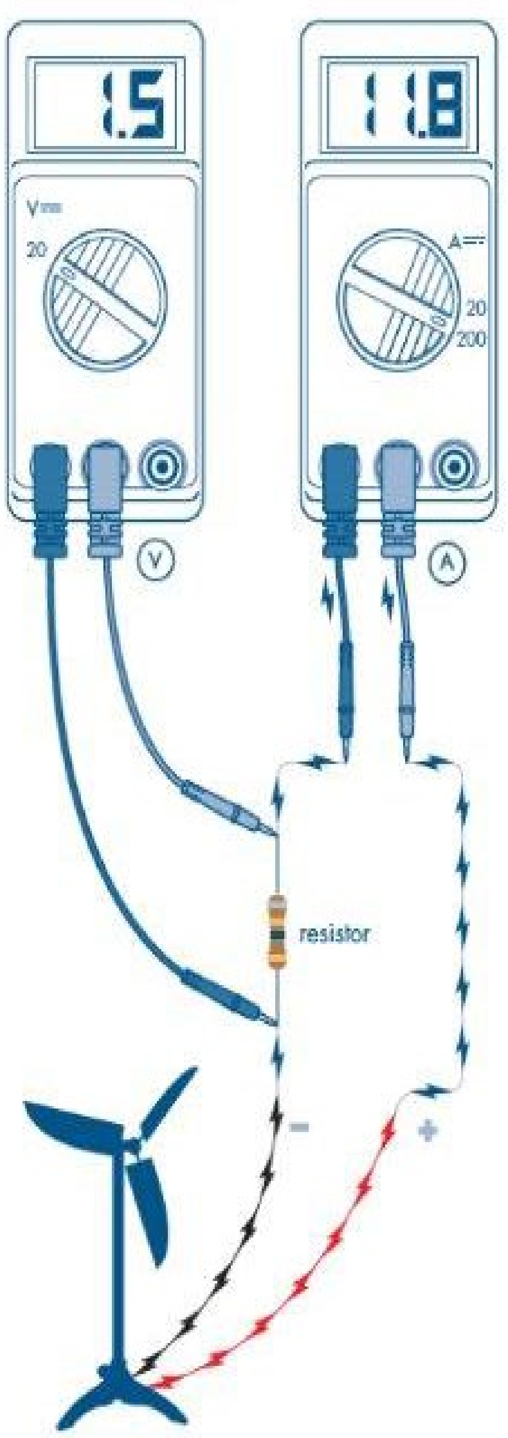
Turbine Blade Building Tips

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.

Safety & Testing Turbine Blades

- It is important to wear safety goggles when constructing and testing blades.
- **NEVER** make blades using metal or any sharp-edged material as they could cause injury while spinning fast during testing.
- Safely set up your testing area like the picture. It is important to clear this area of debris and materials.
- Make sure the center of the fan matches up with the center of the wind turbine. You may need to raise your fan with some books or a container.
- Using the alligator clips, attach your multimeter with the resistor to your motor using the attached instructions.

How to Use the Multimeter



Wind turbines produce electricity, and the best way to understand this is to hook your turbine up to a load or multimeter.

Using a multimeter, you can quantify the voltage and/or current your turbine is producing. Learning how to accurately measure the voltage and current for a range of situations will help you compare data when testing blades, comparing gearing, or changing other variables on small turbines. You will need to record this information on your student datasheet to calculate the power your turbine produces.

Note: The diagram appears you need two multimeters. This is not the case. The connections between the multimeter, resistor and turbine are the same for both measurements. You are only changing the position of the multimeter dial.

Measuring Voltage (*left diagram*)

Attach the wires from the generator to the 30-ohm resister and then to the leads from the multimeter. Polarity is not relevant at this point. To measure voltage, select DCV (v=volt) and set the number to 20.

Place your turbine in front of a fan and let it spin. It is normal for the voltage reading to fluctuate.

Voltage is related to how fast the DC generator is spinning. The faster it spins, the higher the voltage. Record the highest voltage measured on your student datasheet.

Measuring Current (*right diagram*)

To calculate your turbine's power output, you will need to measure current. The unit for current is amperage or amps. To measure amperage, use the same setup between the turbine, resistor and multimeter. Select DCA (a=amperage) and set the number to 200m (milliamps).

Remember: Turn off the multimeter when you are done so the batter will not die.

Source: [Material from Energy Smart CD – Building PVC Turbine]