Wind Turbine Blade Design

by Daniel Moholia

Background

Have you ever wondered how wind turbines work? How do these massive contraptions produce electricity that supplies our homes? I did.

In my experiment, I tested different blades with various angles. I did this in order to discern the most efficient blade design based on voltage output. This experiment helped me understand wind turbine systems on both small and large scales. The construction of these micro wind turbines and testing them helped me understand wind turbine systems and their efficiency, in both the small and large scale.

Purpose

The purpose of my work was to find the most efficient set of blades based on the maximum voltage that could be produced. The question that prompted me to this study was, "How does the material and size of wind turbine blades affect its energy production?"

Hypotheses

I predicted that the composition of the rotor blades would have little or no effect on the maximum voltage output but gather different inertia levels that have a noticeable effect on the number of seconds it takes the blades to get to a maximum, constant voltage output and the number of seconds of revolution after the wind source is turned off.

The actual size of the blades though could have a much more significant affect on the maximum voltage capable of each set. This prediction is based on the fact that in order to get the best demonstration out of the blades, the wind source must be hitting the tip of the blades and bigger blades have bigger tips.

The blade length and material are a baseline for how the angles may improve energy output. By comparing four different readings, each with a different angle, you can derive a conclusion on which angle is most effective and why. This prediction is based on the fact that angles are limited in effectiveness based on the material and size of the blades it is tested on.

Procedure

A model wind turbine with interchangeable blades was constructed. The exhaust from a construction vacuum as a wind source while the voltage output was measured. A video camera was set up in order to capture the information more effectively during and after the wind source was turned off. This was done so that the affect of different blade materials, different lengths, and different angles could be studied

The model wind turbine, with the voltmeter attached was set up with the first set of blades, of the first length, and set at one of the four angles to be tested. The video camera was positioned and video taping was started 10 seconds before directing the wind at the blade. The video camera's main purpose was to capture the length, material and voltage output of the current blades. Angles were recorded by saying them to the camera before each experiment. The camera was left on after the wind source was turned off so that the effect of the inertia on blade revolution before a zero voltage could be measured. Measurement at different blade angles were done, then later the work was repeated with different blade compositions, and also with different blade lengths.

Results

Highest Voltage at 5 Seconds of Experimentation

Blade Length	Material	Angle (deg)	Voltage
Long Blades	MDF	15	0.49
Long Blades	Fiberglass	30	0.43
Long Blades	Plexiglas	45	0.47
Short Blades	MDF	30	1.27
Short Blades	Fiberglass	30	1.06
Short Blades	Plexiglas	15	1.36

By looking at this chart you can derive which angle helped each type of blades be more efficient in the first five seconds of the experiment. This is why not all angles are presented in the table. You can also analyze the voltage to conclude how the mass of the blades could have made it harder for the rotor to start revolving.

Highest Voltage at 65 Seconds of Experimentation

Blade Length	Material	Angle (deg)	Voltage
Long Blades	MDF	12.5	0.07
Long Blades	Fiberglass	12.5	0.32
Long Blades	Plexiglas	12.5	0.16
Short Blades	MDF	12.5	0.83
Short Blades	Fiberglass	12.5	0.9
Short Blades	Plexiglas	12.5	0.69

I selected the readings at 65 seconds because they portray the efficiency of each type of blades and which angle was the most efficient after the power was turned off for 5 seconds. The 5 seconds represents a short time after a windy period when there is no wind and how the different blades would react to the factor based on their inertia and the momentum they were able to gather.

Maximum Voltage Throughout The Experiment

Blade Len.	Material	Angle (deg)	Voltage	Sec. To Vol.
Long Blades	MDF	15	0.55	30
Long Blades	Fiberglass	12.5	0.59	35
Long Blades	Plexiglas	15	0.54	60
Short Blades	MDF	12.5	2.18	35
Short Blades	Fiberglass	12.5	2.07	35
Short Blades	Plexiglas	12.5	2.1	55

Further experimentation is still underway and the conclusion may be different based on the new information gathered.

Conclusion

The three varying blade materials had a large effect on the voltage that they were capable of reaching in a one minute experiment. For example, in the first five seconds of wind power, long, medium density fiber blades, set at 15 degrees, output 0.490 V. In comparison, long fiberglass blades set at 15 degrees, which have a higher density, only reached 0.319 V.

That being said, five seconds after the wind source was turned off, the MDF blades produced 0.030 V. The fiberglass ones, on the other hand, still had a 0.147 V output. The angles were both the same and everything else was the same in the two examples. The only difference was the material of the blades.

I found that the lighter the material was, the stronger the voltage it would output in the first five seconds, and the weaker of a voltage five seconds after the wind source was cut off. It is vice versa for heavier blades. The reason that the blades would start up faster if they were made from lighter material is because the wind force has an easier time getting a constant RPM started. This is also why the constant voltage gets started earlier for the lighter blades than for the heavier. At the end of the one minute experimentation, the heavier blades had a greater voltage output after five second without a source, than the lighter blades. This is because of the inertia, the ability of an object to store energy because of its mass.

The variable that had a moderate effect on the voltage was the angle at which the blades were set. The angle helped improve the aerodynamics of the blades so that they would be able to pass through the air with less drag. The 12.5 / 15 degree angles did this the most effectively and the 45 degree angle accomplished this the least effectively.

The biggest variable that had a difference of around 1.5 V was the length variable. One set with three blades from each of the three materials is 15 cm in length and the other likewise-designed set was 7.6 cm long produced 2.10 V. The main reason that the short sets produced more electricity was because the wind source was probably able to cover the entire blade and rotor surface while the long blade were partially unexposed. Also, the material was lighter and had less inertia so it got to a higher voltage, faster. At the end of the experiment, in five seconds the top voltage out of all of the short propellers was 0.900 V. This means that even though the material was less in quantity and therefore mass, the momentum that it gathered was not weak enough to get it below this from its constant high voltage.

If I were to conduct this experiment once again I would reserve a local gym for a couple of hours so that there is more open space in which the air can move more freely however it wants. Also, I would try to get a larger fan that would cover the entire surface of both propellers. This would make the experiment more reliable. If the blades were to long the outer parts would not catch wind and would act as drag in which case the shorted blades would have an advantage

The results gained from this project could be useful to a person who wants to build a wind turbine for self-generated power. Because of engineering reasons though, you would need more information in order to surpass the problems that come with trying to accomplish this.

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