CALIFORNIA STATE SCIENCE FAIR
2010 PROJECT SUMMARY

Name(s)
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Project Number
S0209

Project Title
Efficient Low-Cost Wind Energy Using Passive Circulation Control

Abstract

Objectives/Goals
Wind turbine blades must change their pitch angle as the wind speed changes to achieve an optimal lift distribution. Circulation control is a way of changing the flow over an airfoil by ducting air through a slot at the trailing edge of the surface. This transforms the shape of the flow, and changes the lift, just as if the airfoil pitch were changed. Conventional variable pitch mechanisms are complex and expensive, but increase the efficiency of wind turbines. This project shows how circulation control can provide the efficiency of pitch mechanisms without their complexity.

A wind turbine can utilize the spanwise pressure gradient along each blade (caused by rotational motion of the rotor), with an inlet near the root of the blade that ducts air to an outlet near the tip, trailing-edge region of the blade. As the wind speed increases, and the RPM increases, so does the centrifugal force, therefore, so does the air coming out of the trailing edge. The flow then passively adapts with the wind speed to decrease the lift at high wind speeds, increasing the turbine's operable range. This project replaces a complex part with a static system that has similar effects but requires no moving parts.

Methods/Materials
I designed, built, and tested a prototype circulation control rotor. I built the blades using stereolithography and CNC foam. To test the rotor, I mounted the turbine to my car, and built an automatic data collection system. I also learned how to run computational fluid dynamics codes to model the effect of trailing-edge blowing on the lift and drag of the blade.

Results
The data taken from the experiment indicates circulation control can significantly affect turbine performance. The new blades increase the range of wind speeds at which the turbine produces power by over 170%. The power distribution at higher wind speeds was lower than expected, perhaps caused by too much trailing edge blowing, or by high drag forces. The CFD cases showed the effect of slot width and jet velocity on lift for this airfoil. Overall, the data from both the prototype and the CFD suggest that passive jet slots could improve the efficiency of wind turbines.

Conclusions/Discussion
The next step is to build a larger prototype to investigate the effects of scaling. This project has the potential to increase the efficiency, reliability, and affordability of wind turbines. Prov. Patent No. 61/306,803 filed Feb. 2010.

Summary Statement
I designed a wind turbine blade with increased efficiency over a range of wind speeds, built a theoretical model using computational fluid dynamics codes, then built and tested a functional prototype,which demonstrated improved performance.

Help Received
David Rodriguez: for teaching me how to run CFD cases. Ilan Kroo: answered conceptual questions and helped with data collection. Tom Muniz: helped with Solidworks. Eric Allison: taught me Xfoil. Colin Johnson/Paul Mendonsa (patent lawyer): helped file patent. Anand Gupta: helped with sensor system.