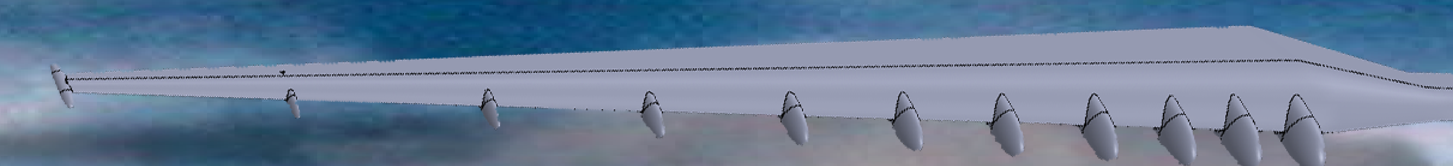
InVentus
Optimization of Wind Energy



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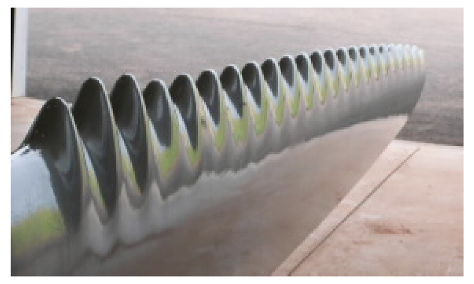
WPI

Absract

Modern wind turbines display only 40% efficiency in harnessing the kinetic energy of wind for electrical generation. Nature has provided engineers with the concept of tubercles. Current tubercle-lined designs require complete replacement of the turbine blade, at a high cost, thus a need exists for a retrofit option to lower the cost of implementation. To analyze the effectiveness of a retrofit versus a fully tubercle-lined airfoil, InVentus obtained a virtual model of a standard turbine blade, then constructed tubercles on a duplicate model, comparing aerodynamic test results with those of fully tubercle-lined designs. This research shows that through further testing and model optimization, such as utilizing more tubercles per blade, a standard turbine blade retrofitted with tubercle units can increase the efficiency and effectiveness of existing wind turbines in similar form to complete replacement of blades, at a far lower cost.

Description

Tubercle-lined airfoils have been researched recently as a replacement to the typical wind turbine blade. Tubercles are a work of biomimicry, in which engineers work to implement the effective traits of nature in technology. Tubercles are the bumps found on the leading edge of a humpback whale's pectoral fins, which compress oncoming fluids into channels, thus increasing the fluid's velocity over the top face of the fin.



Bernoulli's law states that the greater the fluid speed differential between the top and bottom of the airfoil or fin is, the more lift is created. Thus, these tubercles allow for a greater operating range and efficiency, while also reducing noise through a minimization of drag and tip chatter.

RESOURCES
Madsen, P. T., et al. "Wind Turbine Underwater Noise and Marine Mammals: Implications of Current Knowledge and Data Needs." (2006)Web.
Hubbard, H. H., and K. P. Shepherd. "Aeroacoustics of Large Wind Turbines." *The Journal of the Acoustical Society of America* 89 (1991): 2495. Web.
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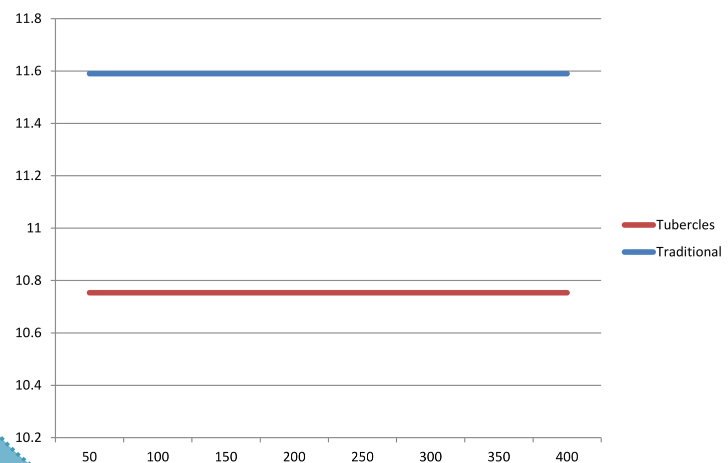
Methodology

This project began with background research based around trying to find a way to minimize the amount of noise emitted by wind turbines. The team decided to focus on the airfoil as a source of noise and efficiency loss. Modern airfoil profiles have improved greatly in efficiency and effectiveness over traditional designs, the most effective of which being the Whalepower corporation's Tubercle-lined design which increases power output by 20%. However, we decided after research that the key to our project would be retrofitting, which would allow existing blades to be improved rather than replaced, as blade replacement is vastly more expensive. We then conducted our interview with Sonia Wharton (Lawrence Livermore National Laboratory) who provided a great deal of information on airflows and atmospheric anomalies surrounding wind turbines that helped us refine our experiment. Our team then modeled a turbine blade in SolidWorks, in addition to making a second model with tubercles affixed to the leading edge of the same blade. After, we ran a fluid simulation in SolidWorks to obtain information about the airflow over and behind the blade. From this, we could calculate changes in the wind's kinetic energy, and thus infer differences in the amount of energy harnessed by the airfoil.

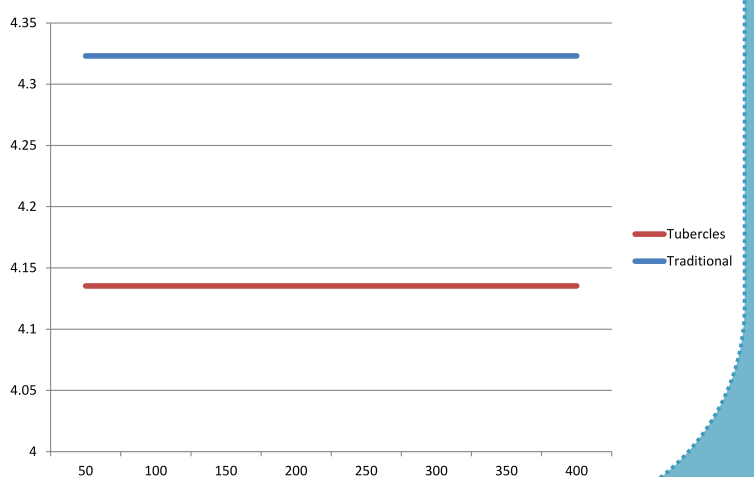
Results

We tested for two main variables in our SolidWorks Flow simulation, velocity and dynamic pressure. We saw a decrease of roughly 6-10% in both of these variables when the tubercles were added to the blades leading edge. The reason that we tested for these two variables in particular is that they are both directly proportional to the kinetic energy of the air behind the blade. By conservation of energy, it can be said that more energy was absorbed by the tubercle-lined blade, as the effected airflow had a lower value of kinetic energy, with no change in the input value of Kinetic energy.

Average Dynamic Pressure vs. Number of Simulations

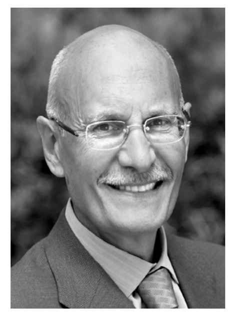


Average Velocity vs. Number of Simulations



Acknowlegements

Sonia Wharton
Lawrence Livermore National Laboratory
Allowed InVentus an interview for information



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GeoEnvironmental, Inc.
Provided CAD model

Conclusions

The tests we conducted have confirmed that a retrofitted blade shows a significant improvement in performance from a traditional turbine blade model, with a 6-10% increase in efficiency compared to Whalepower's 20% improvement. With a more thorough optimization of the tubercle design, the retrofitted blade may show as much improvement as a fully redesigned tubercle blade. The opportunity now exists for corporations to implement tubercles and augment the efficiency of wind turbines in a cost-effective way. All new turbine blades should, ideally, employ Whalepower's tubercle-lined design. However, existing blades should be retrofitted with tubercles to improve on existing technology. This successfully eliminates the need to replace and scrap the existing blades. Yet both of the proposed solutions are not IEC approved. Thus, approval must come before implementation could occur legally.