WindSilo Vertical Axis Wind Turbine

Mechanical and Aerospace Engineering
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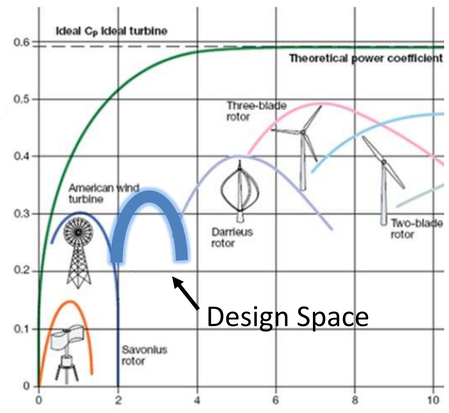
Abstract

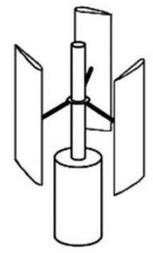
This project researched and designed a vertical axis wind turbine (VAWT) to meet high efficiency and low windspeed capabilities. After researching and testing existing VAWT designs the group decided to further investigate the performance of the LENZ type VAWT. This design was validated through wind tunnel testing and further optimized using computational fluid dynamics (CFD). Using CFD, rapid optimization was conducted using a specialized genetic algorithm. Over 250 designs were evaluated in their efforts to find the optimal wind turbine geometry. The team then participated in the 2022 AIAA (American Institute of Aeronautics & Astronautics) student conference where they won First Place in the Team category for the Midwest Region

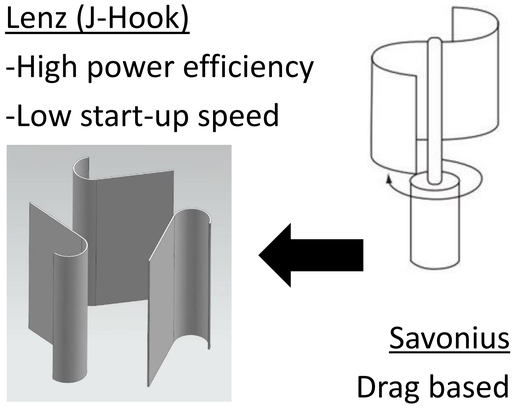
Customer Needs and Requirements

- High Efficiency (~40%)
- Peak power at Low Wind Speeds
- Low Wind Speed Startup
- Competitive Power Output (5 kW)
- Accurate Engineering Model for further VAWT development



Concept Selection





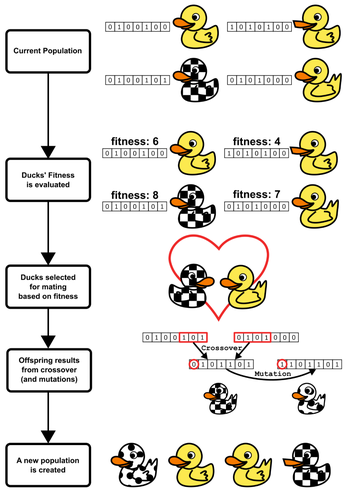
Lenz (J-Hook)
-High power efficiency
-Low start-up speed

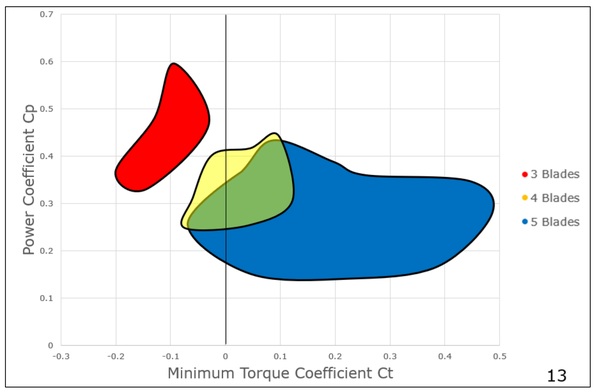
Darrieus
Lift based
High power efficiency
High start-up speed

Savonius
Drag based
Low power efficiency
Low start-up speed

Genetic Algorithm Design Optimization

Design optimization by genetic algorithm



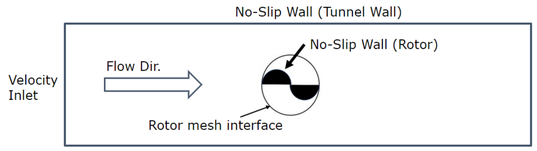


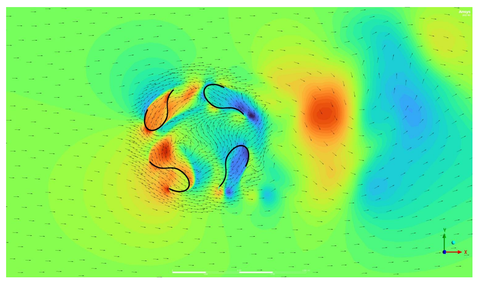
250+ rotor designs evaluated:

- 3 blade high power low torque
- 5 blades low power high torque
- 4 blades is a happy medium

Computational Fluid Dynamics Models

Replicate wind tunnel conditions in a 2D simulated environment





Simulation evaluates performance of rotor geometry

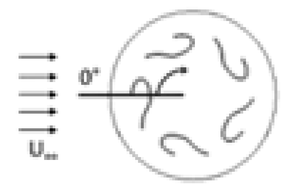
Power Coefficient

- Efficiency of power generation
- Determined by measuring power produced by the rotor

$$C_P = \frac{Power\ Gathered}{Wind\ Power\ Available}$$

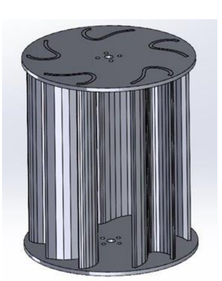
Torque Coefficient

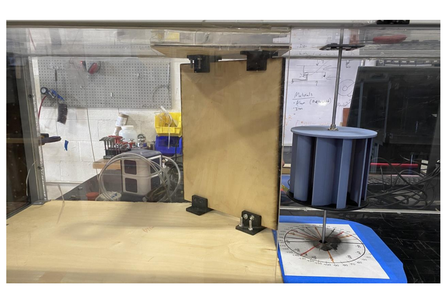
- Non-dimensional torque
- Positive minimum torque determines if rotor will begin rotation at all starting angles



Wind Tunnel Validation

- Make real life models to validate CFD predictions
- Use a Dynamometer to measure power performance of 3D printed models
- Use a torque transducer to measure static performance
- Observe 3D effects not present in 2D CFD

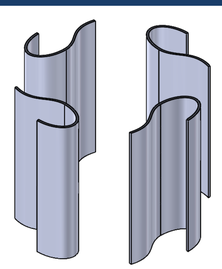


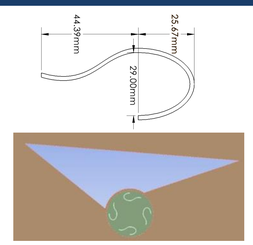


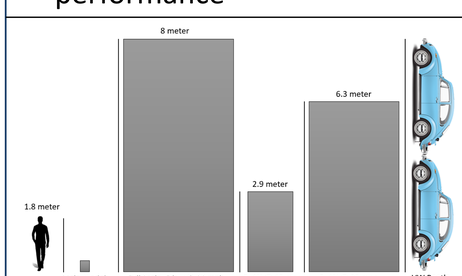
Final Design

Final Design

- 4 blades
- CFD optimized blade geometry
- Geometric IGV design for increased performance







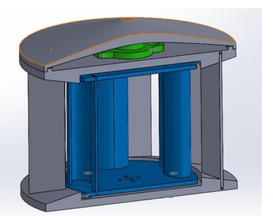
Size considerations

- 34% efficiency
- Large size needed for 5 kW power output

Future Work/ Acknowledgments

Future Work

- Optimization of inlet guide vanes
- Blade and/or IGV actuation
- Development of a full-scale model
- Real world wind condition testing
- Development of generator components and electrical systems



Acknowledgments

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