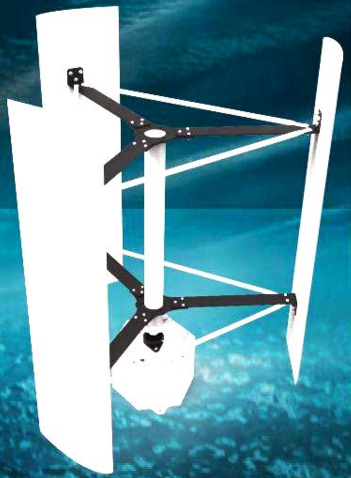
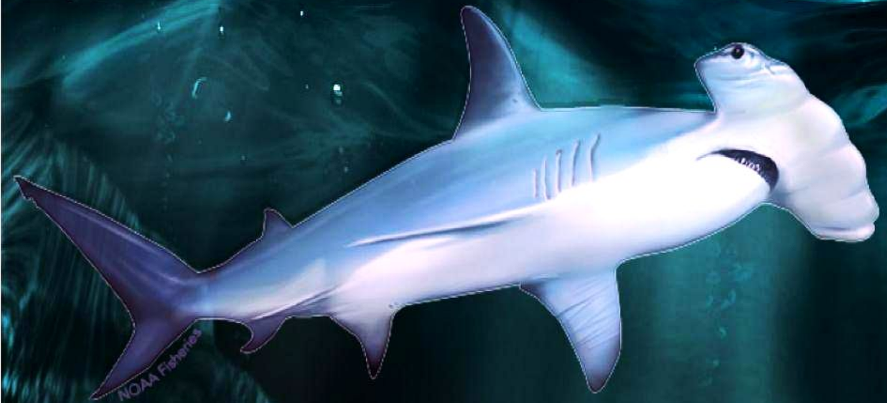
HAMMER: Hammerhead-Adapted Modifications for Maximizing Energy Retrieval





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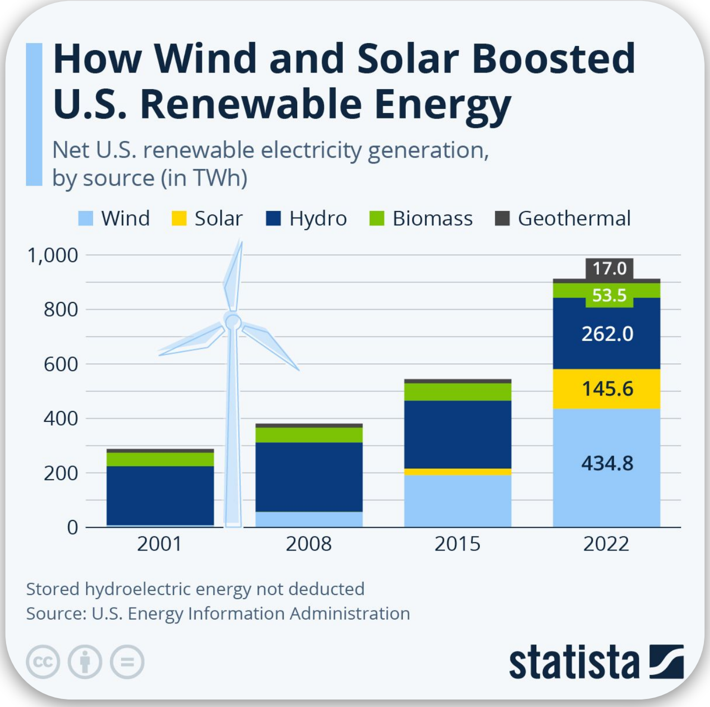
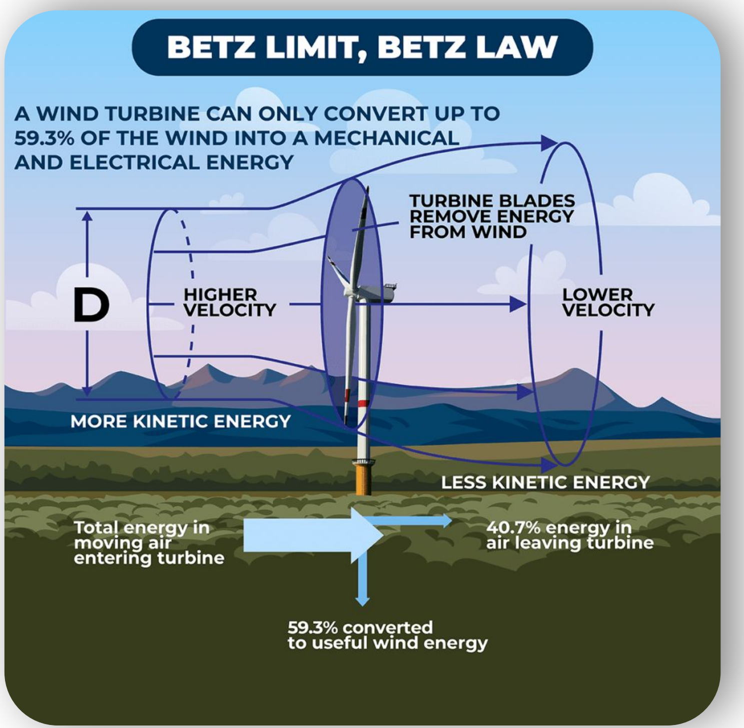
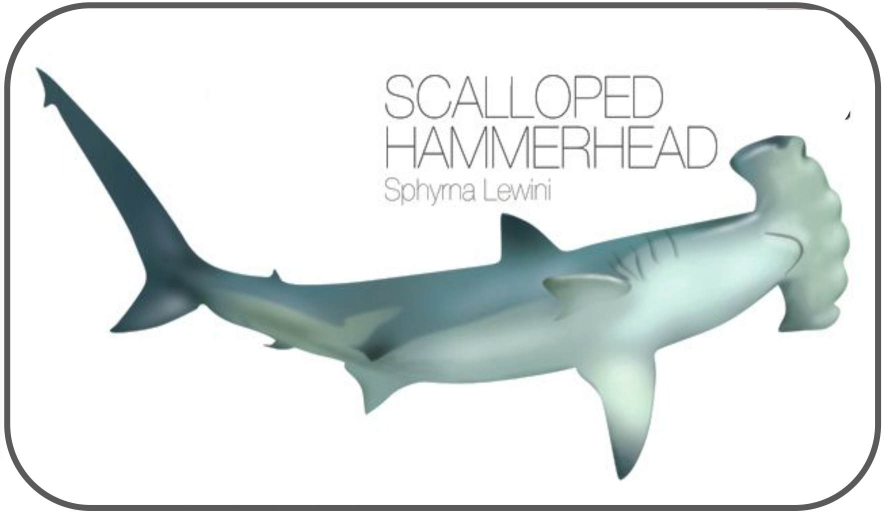
Wind Energy & Betz Limit





VAWT & Hammerhead

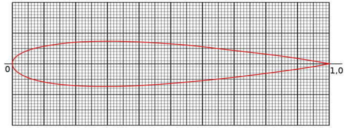


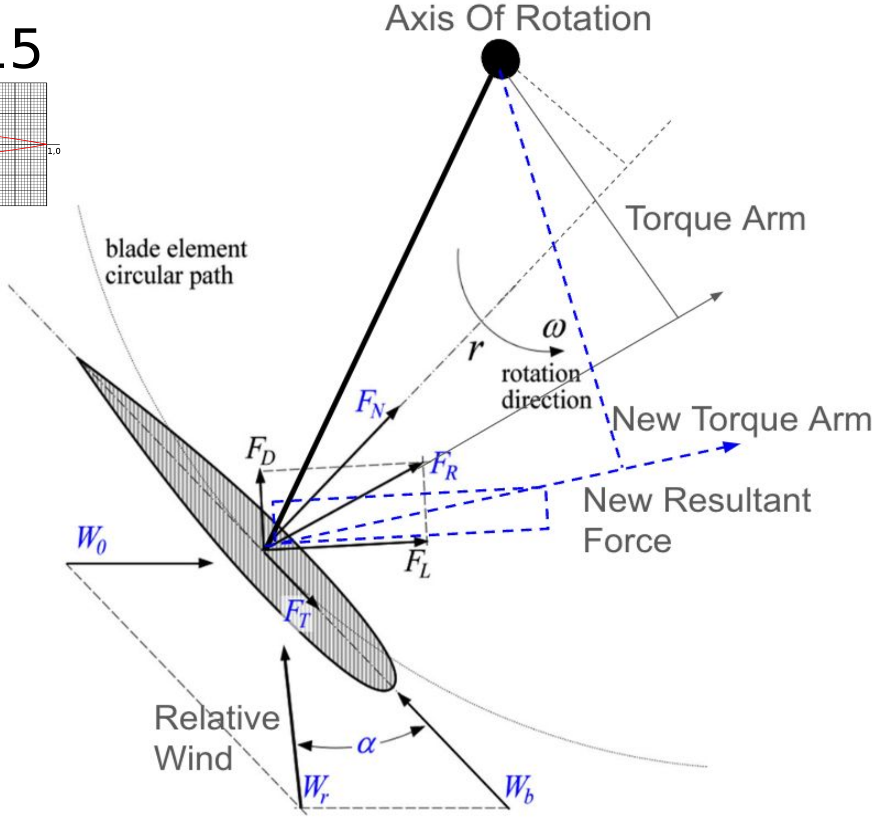
- VAWTs have distinct advantages
- They operate from 40-50% efficiency

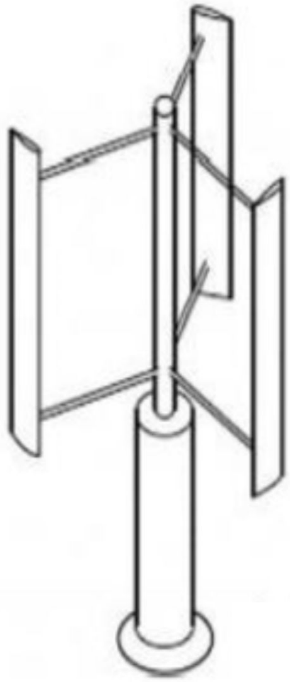
- Biomimetic Design
- Scalloped Hammerhead Inspired Blades

Physics of an H-Darrieus VAWT

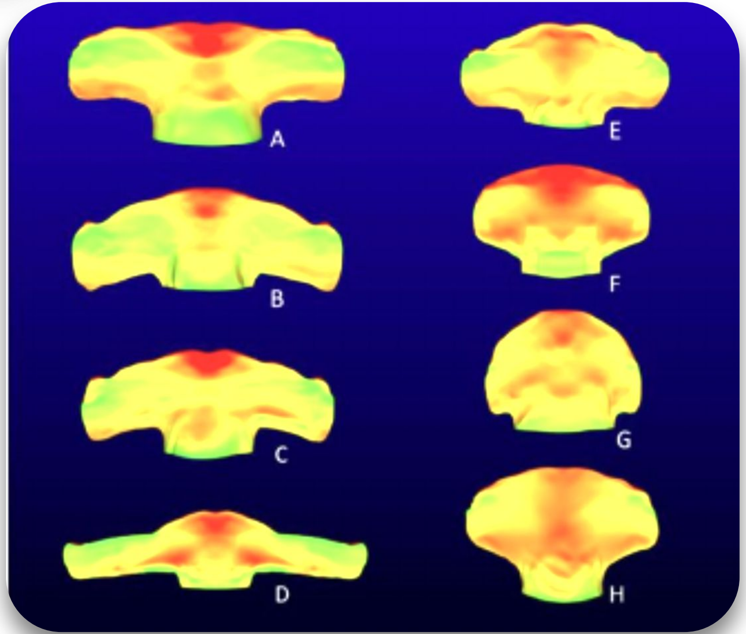
NACA 0015

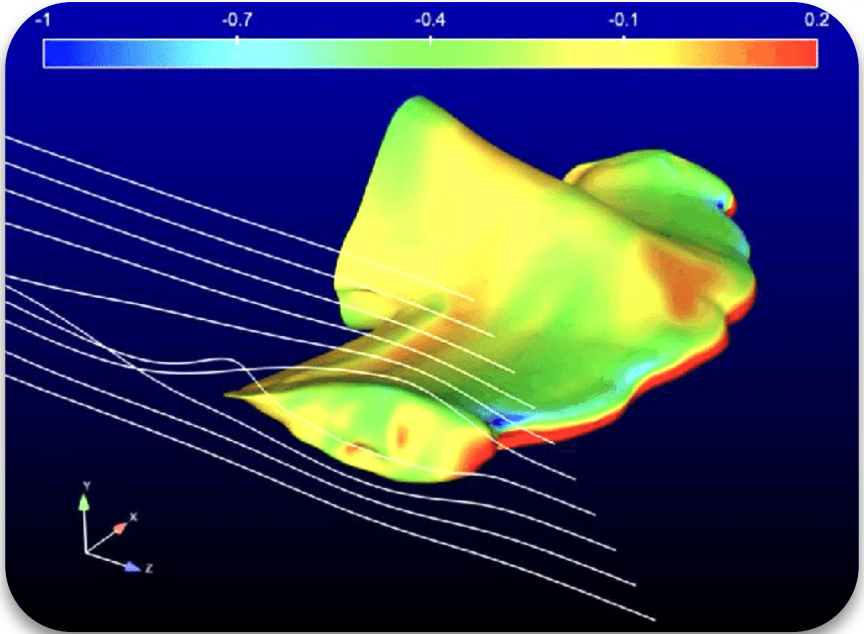






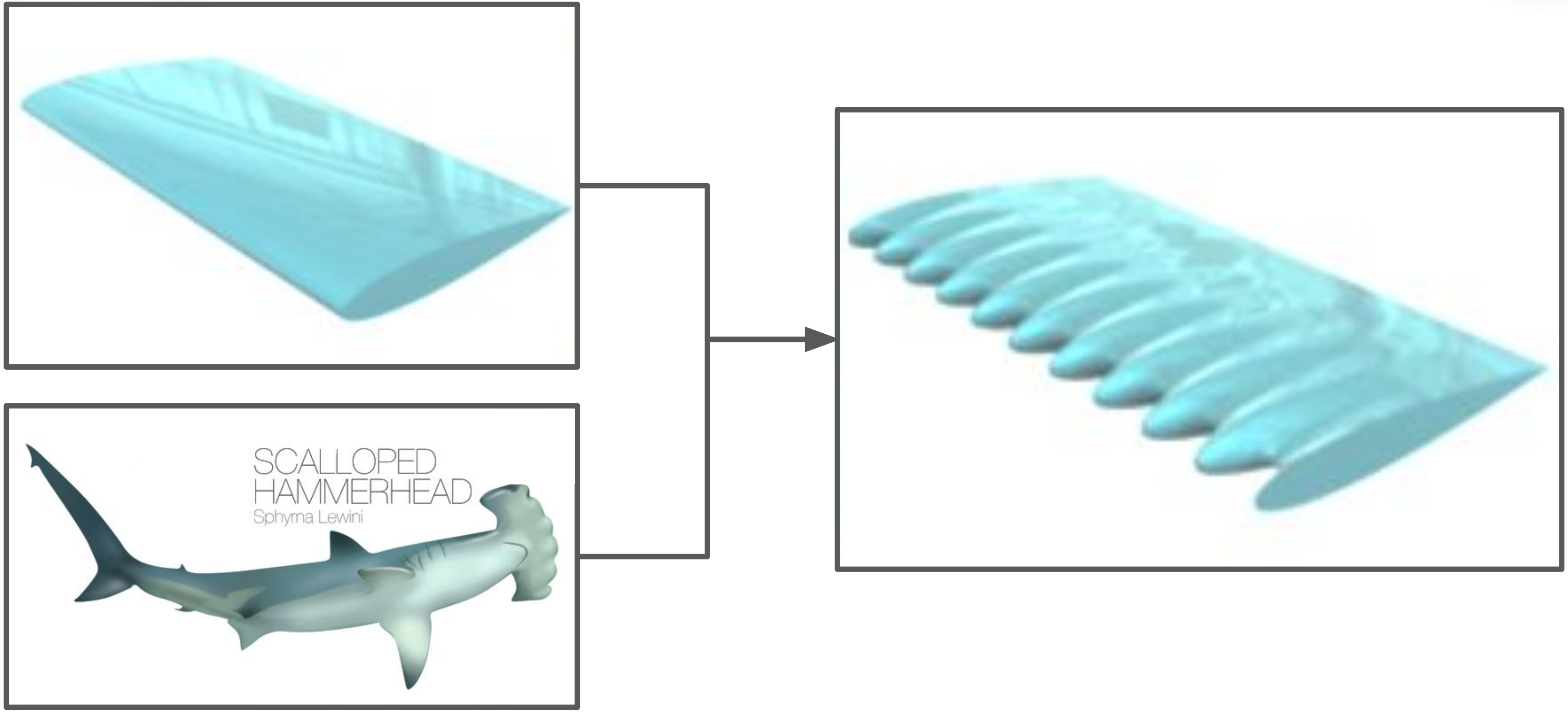
Hammerhead Shark Hydrodynamics



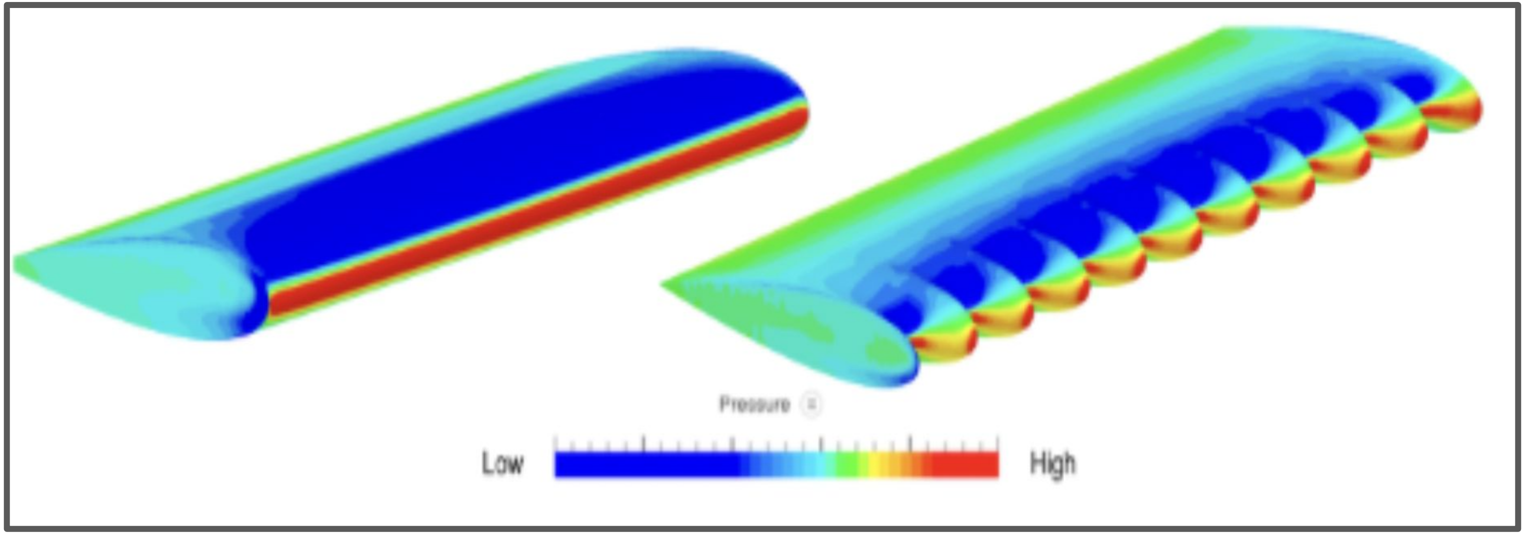


Gaylord, Matthew & Blades, Eric & Parsons, Glenn. (2020). A hydrodynamics assessment of the hammerhead shark cephalofoil. Scientific Reports. 2020. 14495. 10.1038/s41598-020-71472-2.

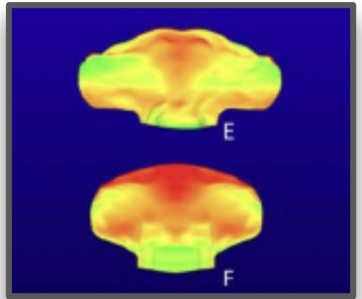
The Scalloped Hammerhead Shark



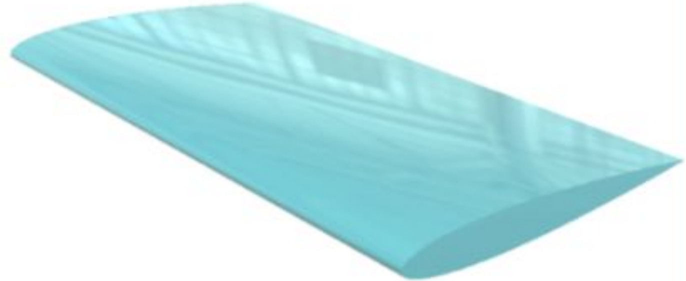
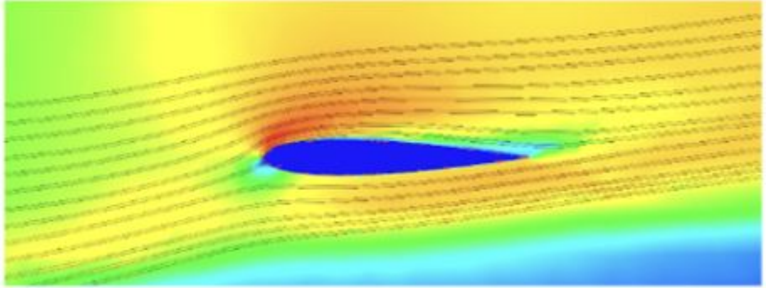
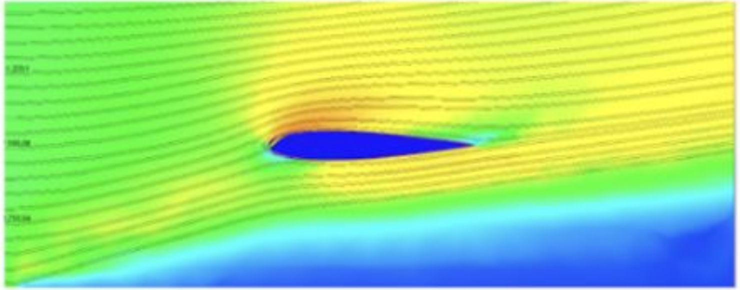
Reduced Leading Edge Drag



1. Tubercles provide sharper entry point into wind stream.
2. This reduces leading edge drag.



Reduced Trailing Edge Drag

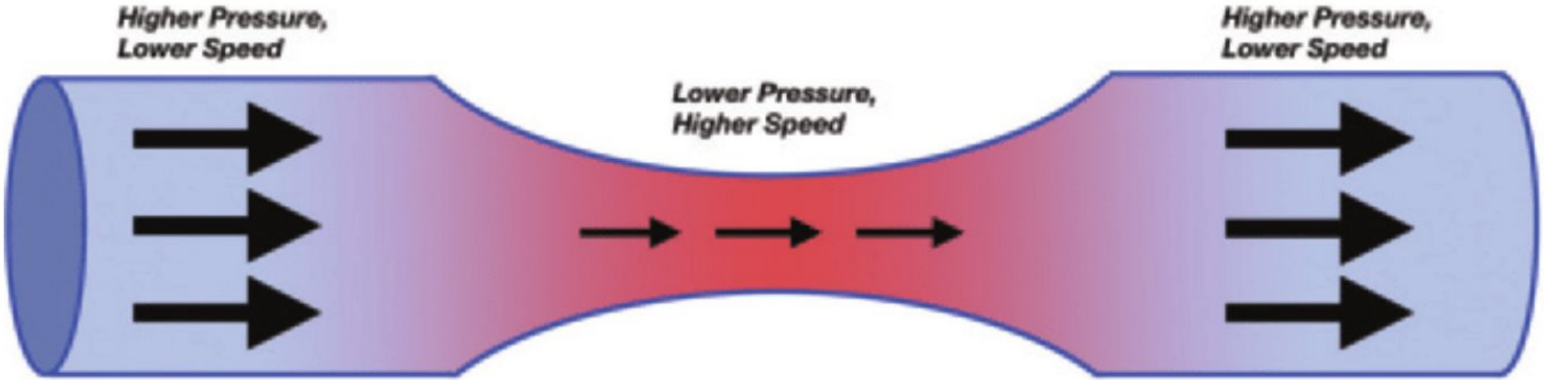
3D model		
CFD sim		

Tubercles reduce trailing edge drag by delaying flow separation.

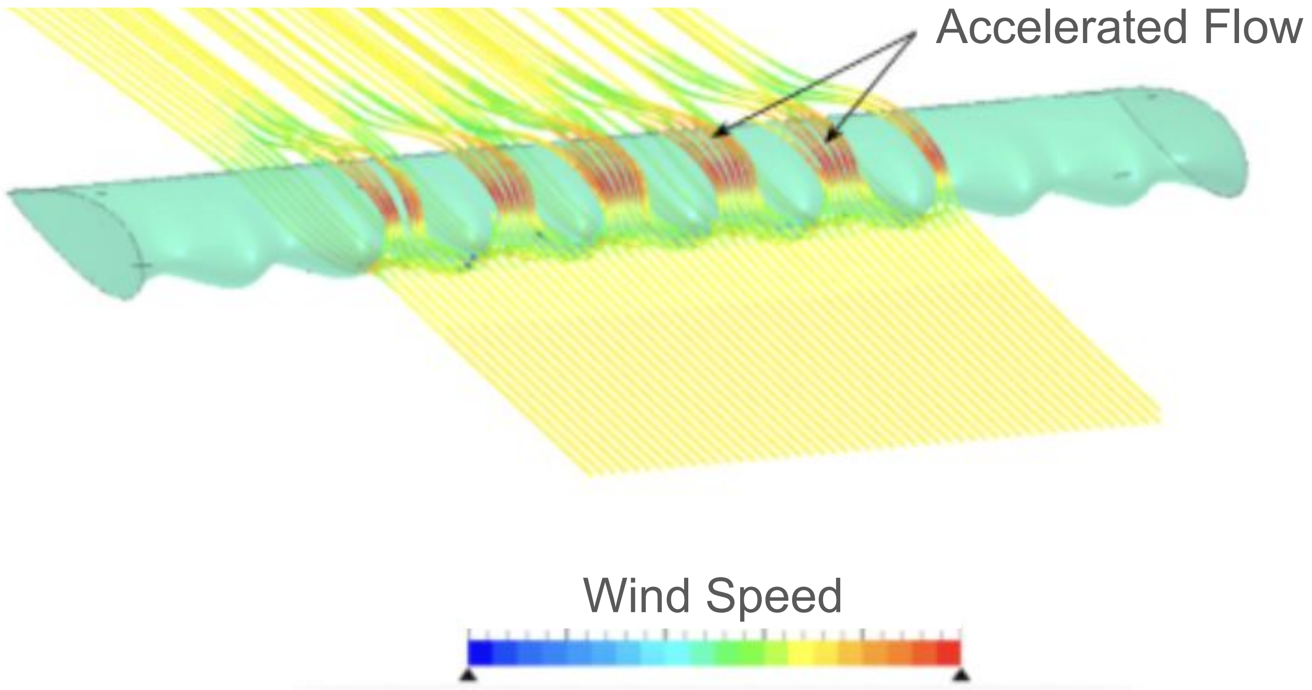
Tunneling Effect

Bernoulli's Equation

$$P_1 + \frac{1}{2}\rho V^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V^2 + \rho g h_2$$

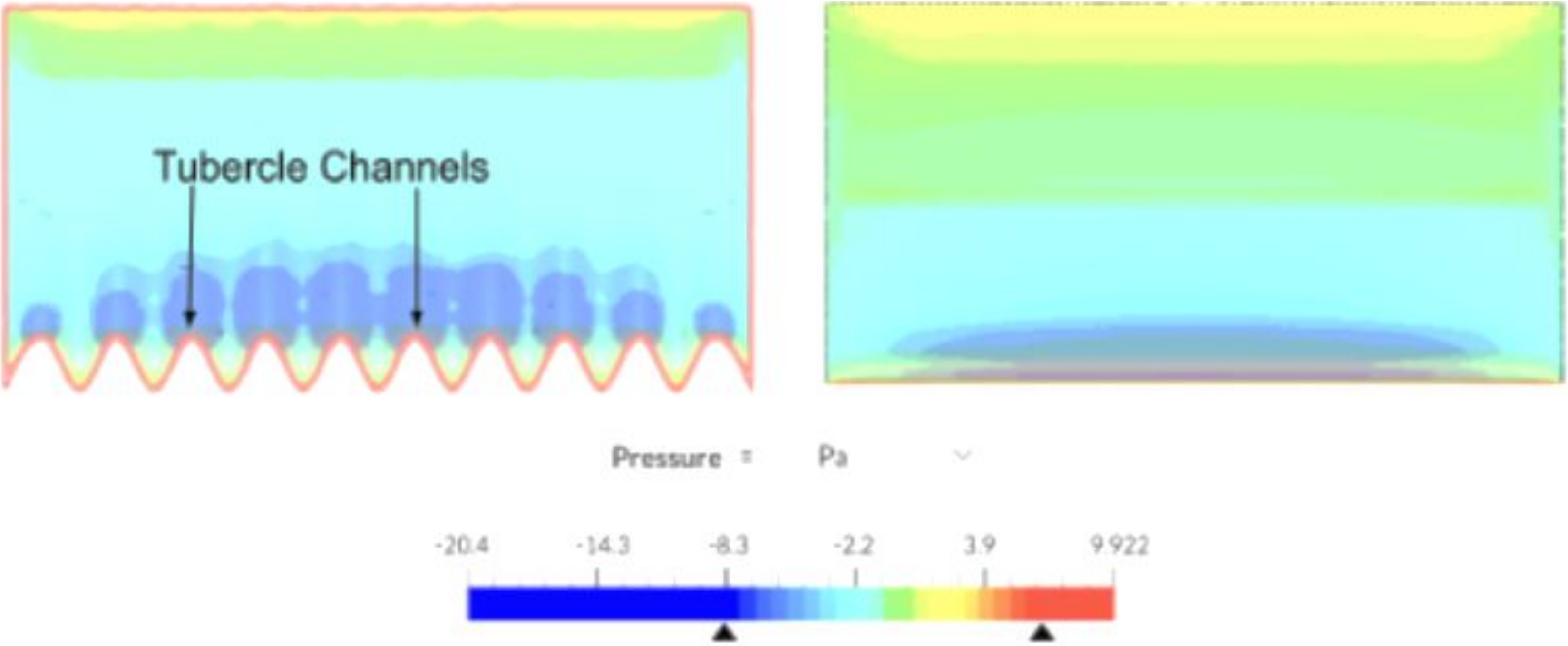


Flow Acceleration



The channels constrict the flow, forcing them to accelerate and increase lift

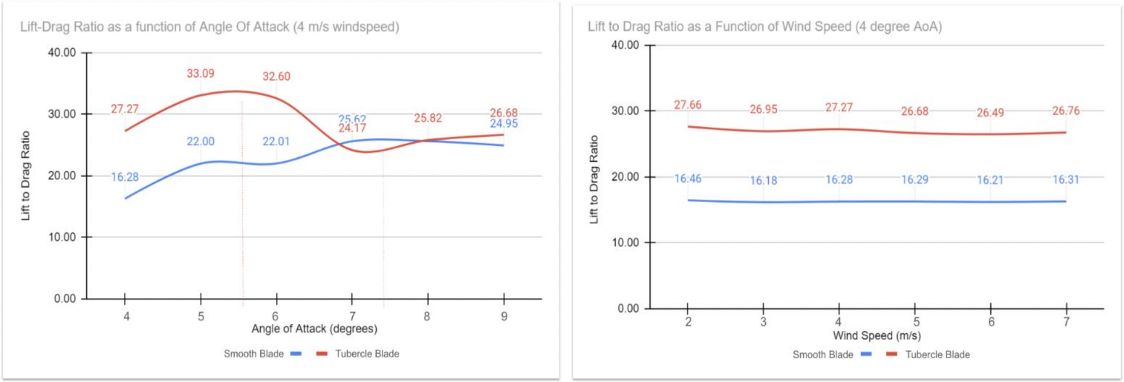
Increased Lift



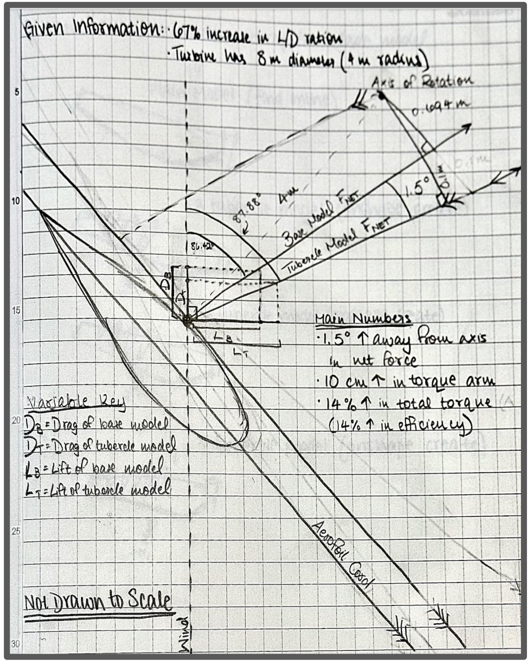
Top surface of the wing showing the pressure field. The tunneling effect showing lower pressure in the ridges (left) as opposed to lesser pressure on the top of the wing (right).

Numerical Results (CFD)

L/D Ratio at Varied Wind Speed and AoA

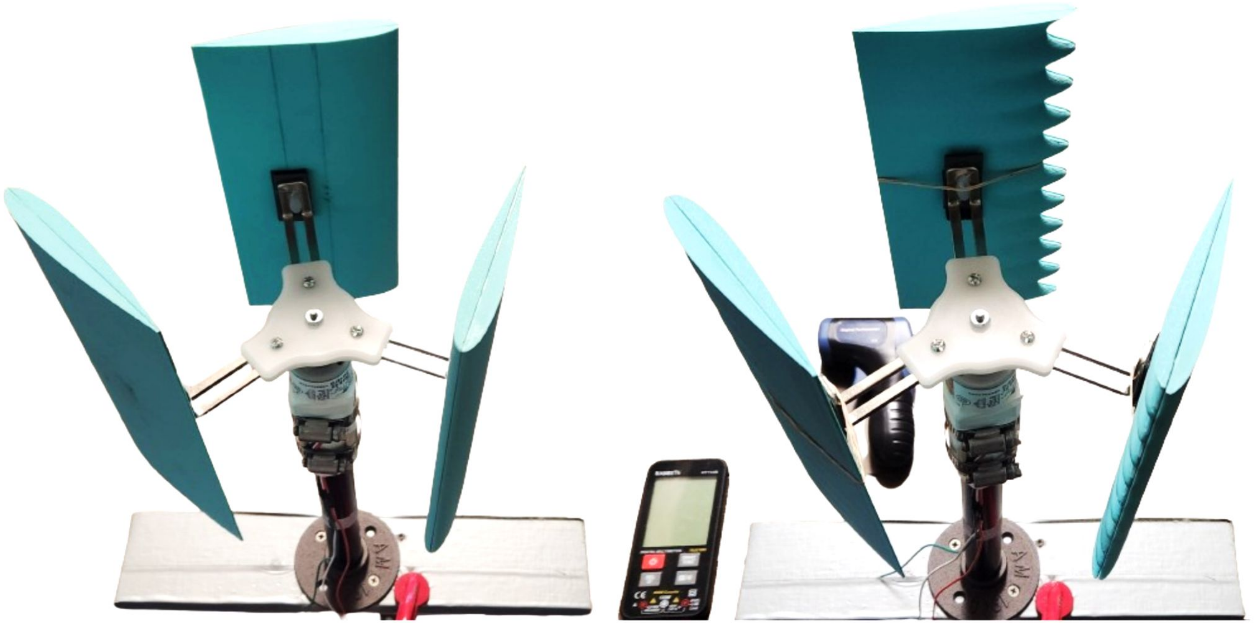


L/D Ratio vs. Angle of Attack (left) and L/D Ratio vs Wind Speed (right)



67% increase in L/D ratio resulting in **14%** increase in torque

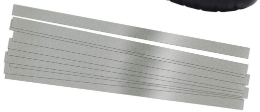
Physical Test Setup



3D Printed Blades assembled on a fully operational wind turbine with base model (left) and tubercled model (right)

Tachometer

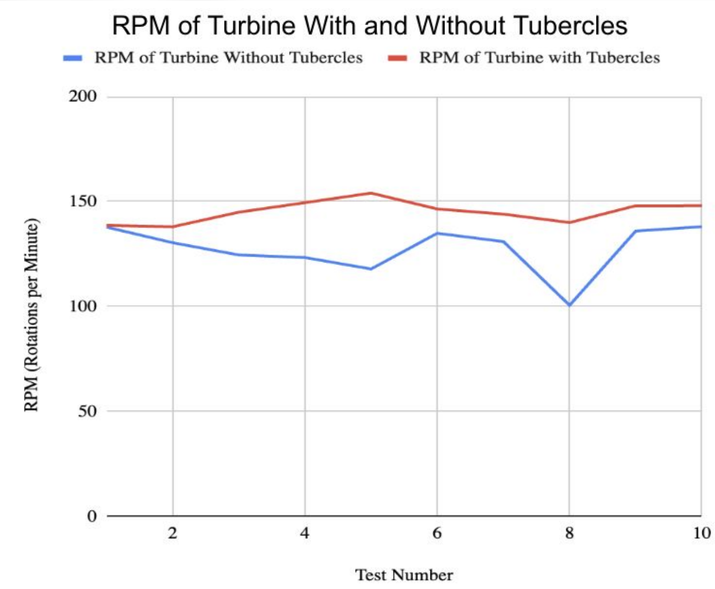
Reflectors

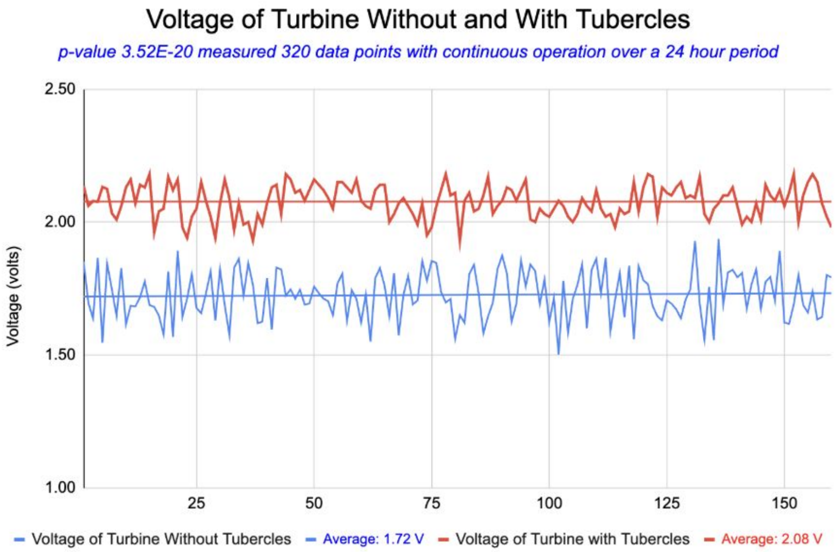


Dynamo

Multimeter

Physical Testing Results (RPM & Voltage)

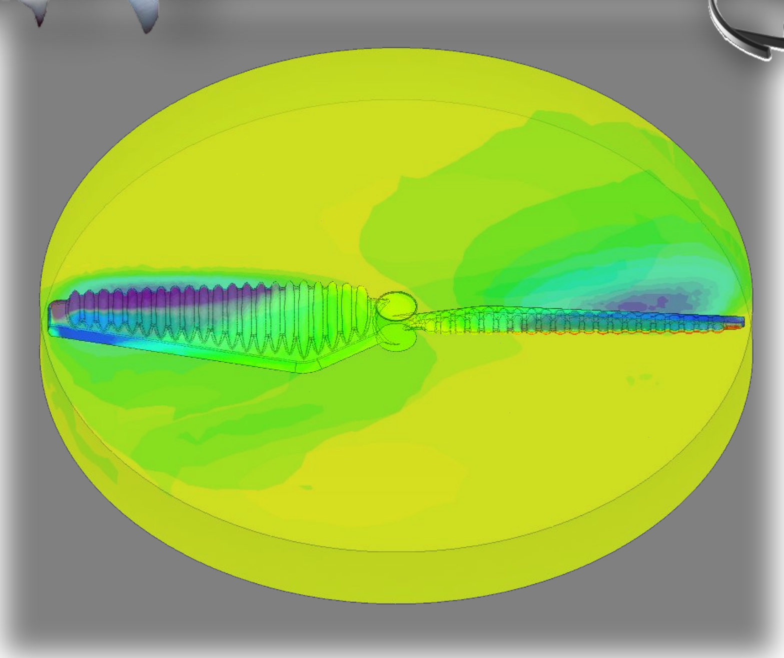


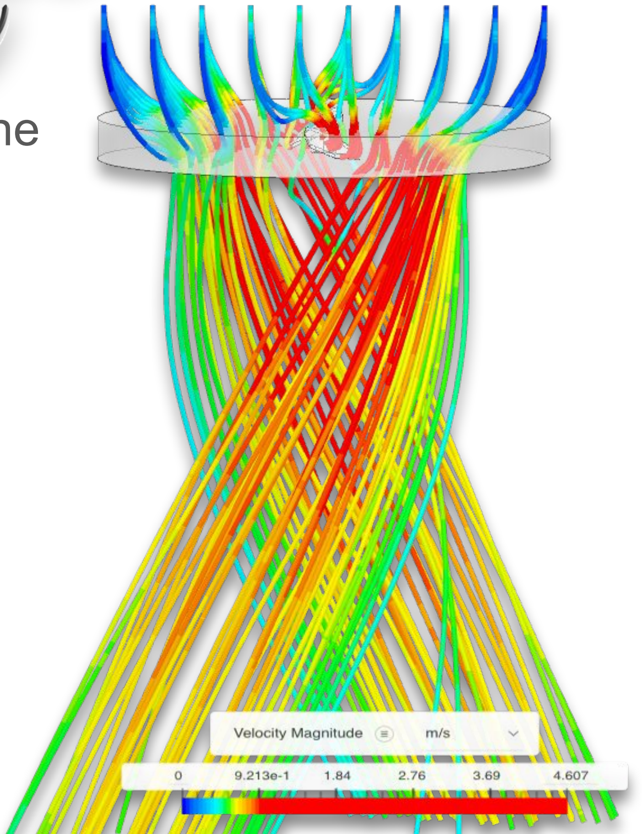


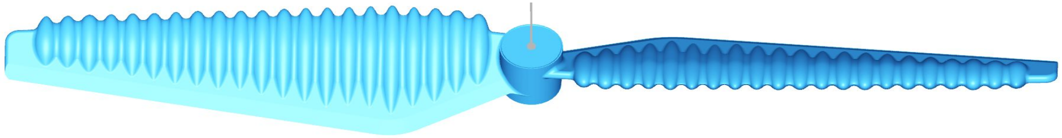
The physical experiment results showed a **12%** increase in rotational speed and a **20%** improvement in energy capture efficiency across 170 tests for the tubercle-modified turbine. The voltage graph indicates more consistent output for the tubercle turbine. Similar to how tubercles stabilize flow around hammerhead sharks, they contributed to enhanced flow stability in the turbine.

Future Work

Ryze Tello Drone







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