DESIGN AND CFD ANALYSIS OF BIOMIMETIC TURBINE BLADE FOR LOW VELOCITY TIDAL STREAMS

Emil Christian R. Luna[1a*], Seyed Hamed Hashemi Sohi[1b]

[1]School of Mechanical and Manufacturing Engineering, Mapúa University, Intramuros, Manila City

[a]ecrluna@mapua.edu.ph, [b]shhamedsohi@mapua.edu.ph

ABSTRACT

A Horizontal Axis Tidal Turbine blade was designed and optimized for low-velocity tidal streams. The optimized blade is integrated with a biomimetic concept that took inspiration from the pectoral fins of Humpback Whales. Three different blade configurations are subjected to steady-state filtering to see which biomimetic configuration has the highest C_L and GR at 0° to 20° AoA. The result showed that the 0.2C configuration outperforms the other two. 0.2C was then integrated into a HATT setup and was subjected to transient simulation. The results showed that the biomimetic HATT outperforms conventional tidal turbines. The design operates at higher TSR with comparable power output at (a) same inlet velocities and (b) the same swept area.

METHODOLOGY

Phase I: Biomimetic Turbine Blade Geometry

Design and optimization of baseline blade

Biomimetic design conceptualization

Integration of Biomimetic concept & baseline blade

Phase II: Steady-state Filtering

Steady-state filtering → Blade selection

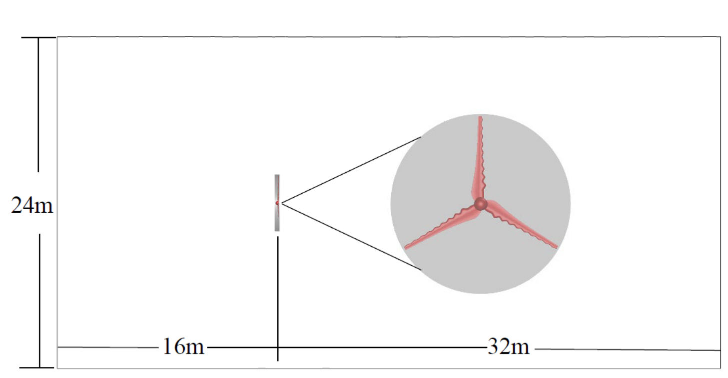
Phase III: Transient Simulation

Biomimetic HATT → Transient simulation → Post process → Results

- NREL S814 airfoil
- Designed and optimized to produce a slender blade.
- 0.0C is the baseline blade. 0.15C and 0.2C are the biomimetic configurations
- 0.035mm is the first layer height to produce a y^+ value of 1
- 6.8 million cells is the optimum value for the mesh setup
- In steady-state filtering, the blades are subjected to 0.5m/s inlet velocity and transitioned from 0° to 20° AoA.
- Biomimetic HATT was subjected to transient simulation at an inlet velocity of 0.5, 0.64, and 1.136m/s at a constant TSR of 6.

Mesh Independence Test

Grid Elements (million)	Coefficient of Power	Coefficient of Thrust
4.5	0.333	0.810
6.8	0.329	0.809
9.1	0.328	0.807



CONCLUSIONS

The biomimetic HATT performed better than other conventional tidal turbine designed for low-velocity tidal streams. This biomimetic blade operates at higher TSR with comparable power output at (a) the same inlet velocities and (b) the same swept area. Furthermore, the high TSR operation reduces cost in the design of the power take-off system since it can employ direct drive mechanisms.

For recommendations, a study in the wake characteristics and noise measurements can be conducted. The effect of these could be studied to see to what extent it affects the biomimetic blade design. Furthermore, this will also give more understanding of the tubercle effect that was produced by the sinusoidal leading-edge.

INTRODUCTION

Tidal Stream Energy

Pros
1. Can be predicted
2. Clean energy
3. Permanence

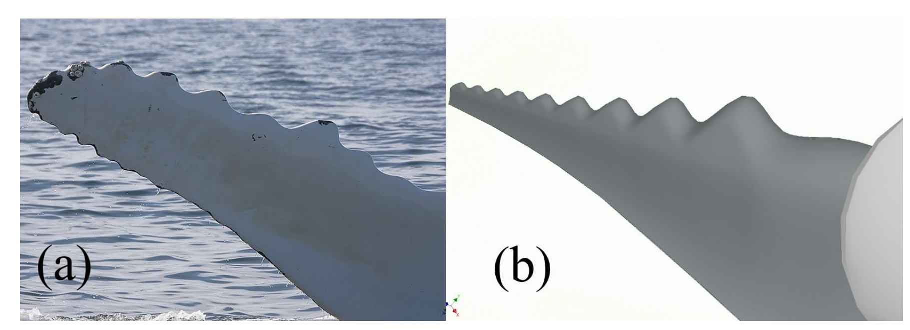
Cons
1. Site specific
2. Intermittence
3. Biofouling

Conventional tidal turbines operate at 1.852 to 2.521 m/s stream velocity

Problem: Viability of tidal technology is low

Solution: Nonconventional design approach - Biomimicry

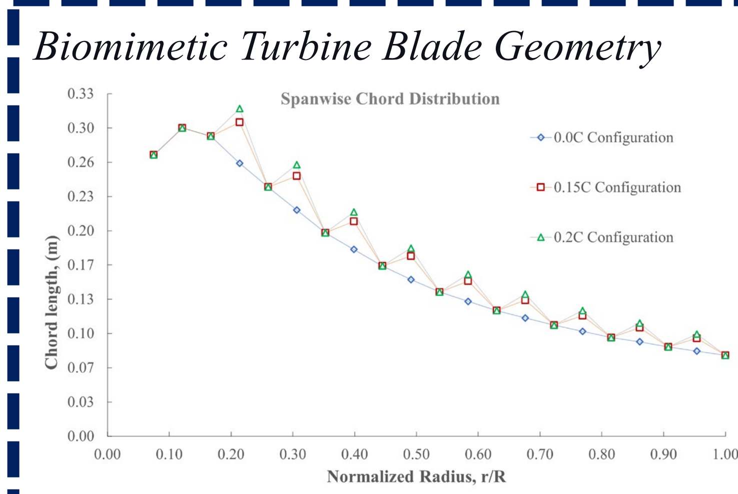
Result: Increased viability due to utilization of low-velocity streams



Comparison between (a) the actual flippers of the Humpback Whale, and (b) 0.2C blade configuration with NREL S814 airfoil.

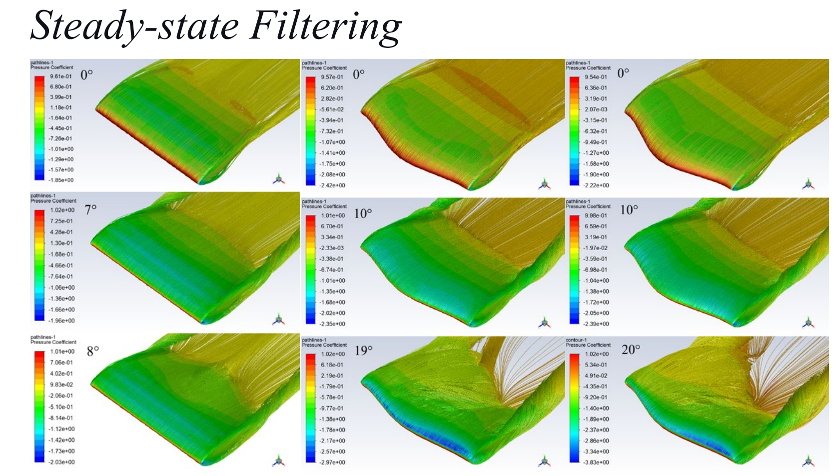
RESULTS AND DISCUSSIONS

Biomimetic Turbine Blade Geometry

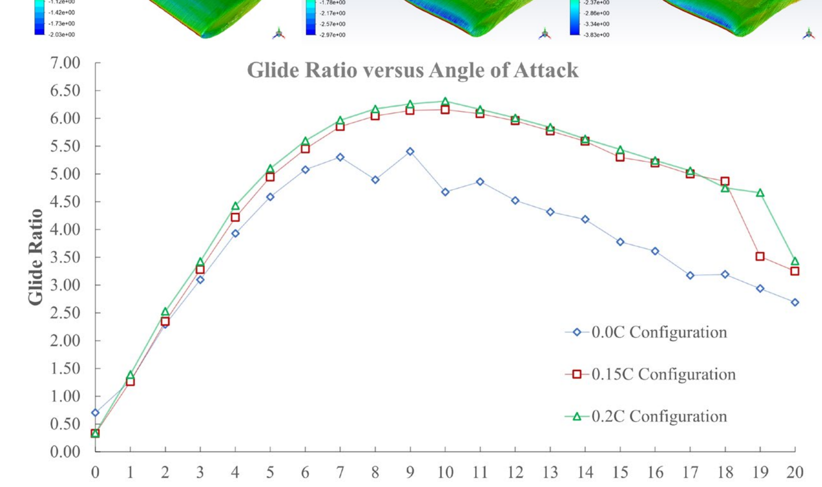


To produce protuberances at the leading edge of the blade, the modifications of the chord length of the blade element was done alternatingly depending on the specified amplitude of the biomimetic configuration.

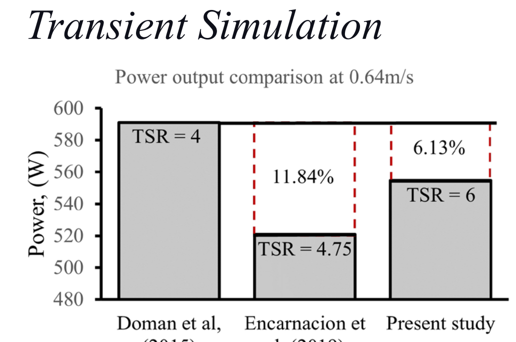
Steady-state Filtering

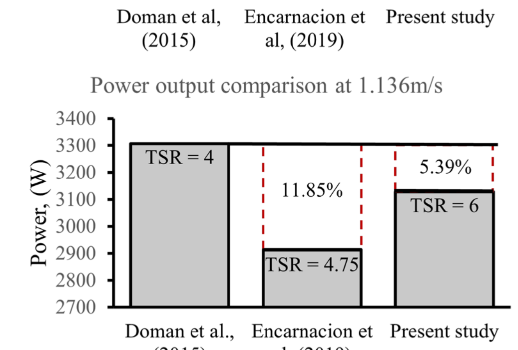


The result of the steady-state filtering showed that the 0.2C configuration has the highest GR, which is 6.311 at a 10° angle of attack. 0.2C also produced a C_L of 0.611 at 19° before it stalled at 20°. 0.15C produced a GR of 6.155 at 10° and C_L of 0.588 at 18° before it stalled at 19° while the baseline blade, 0.0C, stalled at 8° and produced a GR of 5.301 and C_L of 0.240 at 7°. From this, it can be concluded that the biomimetic configuration greatly improves the glide ratio, coefficient of lift, and stall angle of the blade.



Transient Simulation





Summary of the output of Biomimetic HATT

Parameters	Inlet Velocities, (m/s)		
	0.5	0.64	1.136
TSR	6	6	6
ω, (rad/s)	1.5	1.92	3.41
Thrust, (N)	1299.09	2134.2	6742.34
Torque, (Nm)	174.91	288.96	918.05
Power, (W)	262.37	554.79	3128.73