Development of a Novel Oscillating Water Column Using Computational and Experimental Methods

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https://youtu.be/ZYniDaQAaF4

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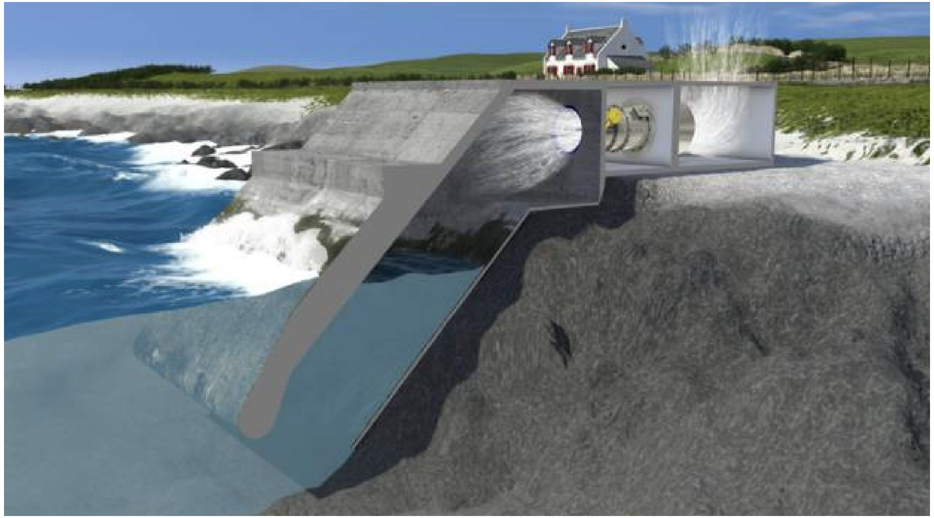
Clean Energy Education & Empowerment (C3E)

Introduction

- Earth's natural resources are being exploited for the purpose of electricity production at alarming rates, the need for clean energy is greater than ever.

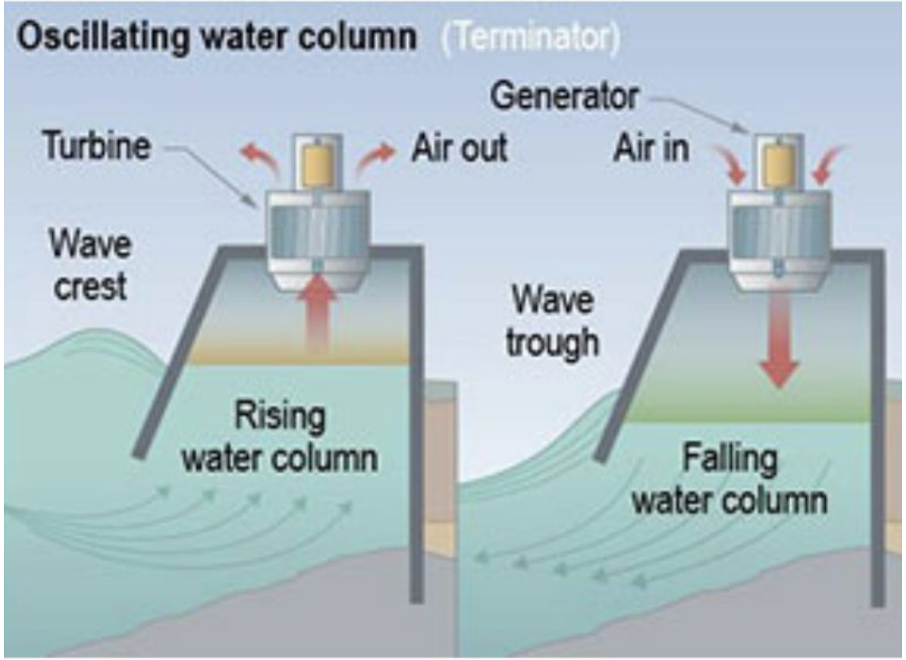
- About 25% of 2016 global greenhouse gas emissions: The burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emissions.

- Our team will be designing a wave energy conversion in the form of an Oscillating Water Column with the goal of having a efficient , cost effective, reliable device that can harbor the natural power of the ocean's waves right off the coast of North Carolina.



Objective

- Our main goal for this project is to use experimental and computational approaches to build on the findings of paste years and design an optimized OWC.
- As a personal goal of our team, we want to design a full system with a low torque generator completing our OWC and allowing use to have useable clean energy



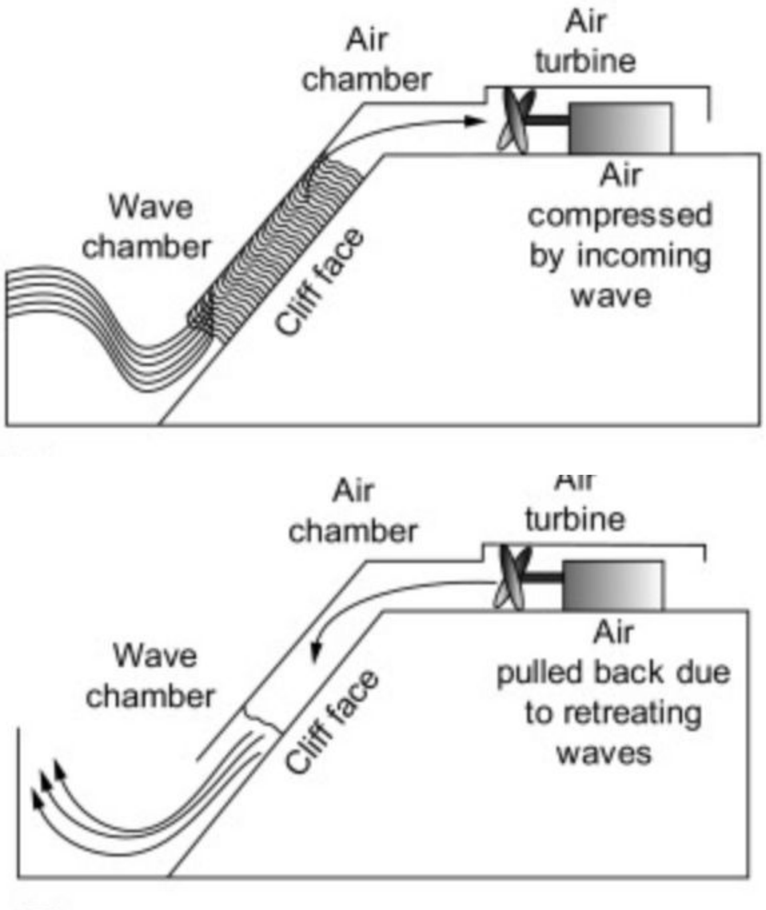
Methods: How does it work?

Step 1: Waves enter the chamber causing the air inside to oscillate.

Step 2: The moving air creates a piston-like effect that powers the movement of the Turbine

Step 3: By connecting the turbine to a generator, the OWC converts mechanical energy to Electrical energy.

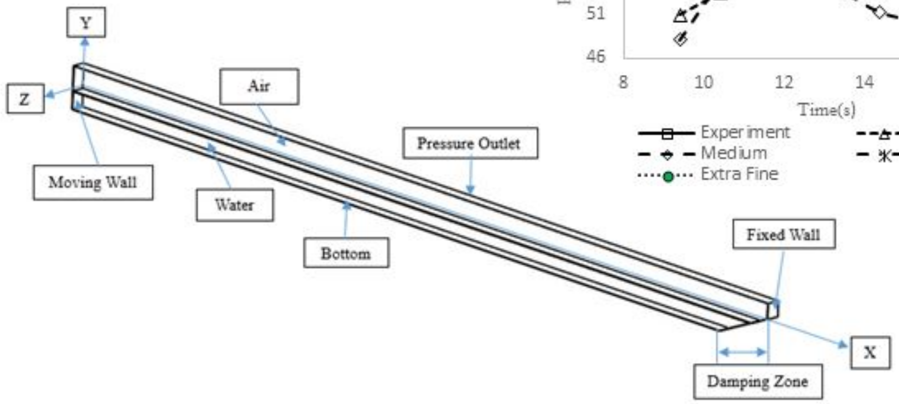
Step 4: Energy is stored and transported in some manner so that it may be usable

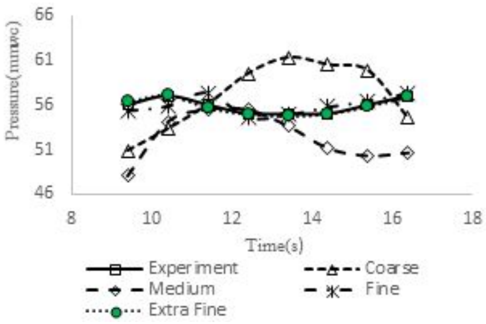


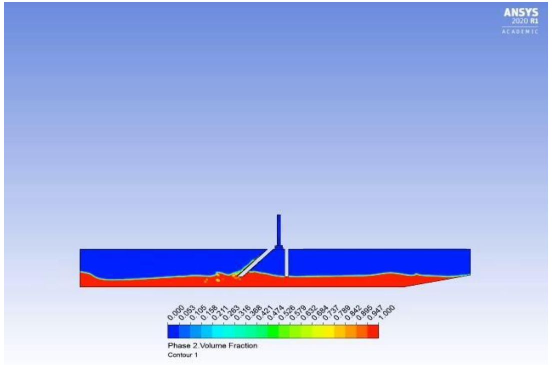
Methods

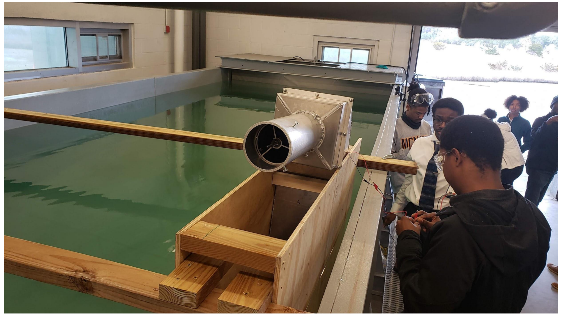
Numerical Experimental Wave Tank

- Dynamic Meshing technique
- Unsteady RANS or Inviscid Multiphase (air, water) flow simulations
- Time-dependent user defined function (UDF) to simulate flap-type wavemaker
- Uniform hexahedral Meshing









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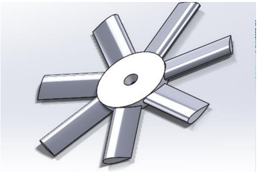
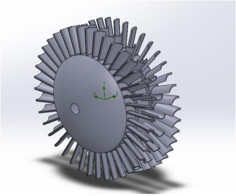
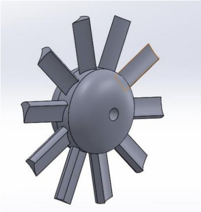
Results: Turbine and Chamber


Turbine:

- Three turbines were tested and in the end, the NCAT Davis-Gay turbine was selected ad the final geomtry for the OWC.
- The Davis-Gay Turbine features heavier blades that create more momentum when rotating, double-sided ramp shape to ensure uniform bi-directionality, and also acts as a flywheel storing energy when there is no air pressure.

Chamber:

- Two initial chamber designs were selected after testing there were no signs of power production potential so two more designs were created.
- The Cobra (S-shaped) turbine proved to be the only chamber design to allow for turbine movement

Results

Using the selected geometries the team designed ab OWC that featured the Gray-davis turbine and Corba chamber designs. The OWC was tested at different heights and frequencies the following results were recorded. Including the RPM of the turbine, the wind velocity, and the efficiency of the OWC.

RESULTS – VARYING WAVE HEIGHT

Control: Water Level = 1.3m						
Wave Height (m)	Wave Period	Seed	Max Wind Velocity (m/s)	RPM	Power (HP)	Efficiency
0.05	1.2	2	0.4	~500	0.821	16.5%
0.08	1.2	2	1.1	~730	2.004	40.1%
0.15	1.2	2	1.4	~910	2.67	55.9%

RESULTS – VARYING WAVE PERIOD

Water Level 1.3m						
Wave Height (m)	Wave Period	Seed	Max Wind Velocity (m/s)	RPM	Power (HP)	Efficiency
0.08	1	2	0	0	0.000	0.0%
0.08	1.1	2	0.2	183.33	0.396	8.0%
0.08	1.2	2	1.1	364.6	2.004	40.1%
0.08	2	2	0.9	181.67	0.398	8.0%

Conclusions

- Discovery of two geometries that can be paired together to allow for efficient ocean wave energy power conversion.
- Determined strong efficiency correlation between wave frequency and device resonance frequency
- Potential analytical methods to increase efficiency for both chamber and turbine using experimental and computational data from previous designs
- Develop multi-scale experimental techniques and incorporated high-fidelity CFD into the design process
- Data suggest that adaptable chamber designs can improve OWC performance at off design conditions
- Exploring non-linear scaling parameters for OWC design optimization based on Froude and Reynolds number

Future work

- Explore additional novel chamber designs using our multidisciplinary design approach.
- For the turbine, we plan to focus on better quality airflow to improve efficiency.
- Study three additional designs for the turbine and compare the performance to the Wells turbine.
- Couple a low torque generator to the turbine to convert the mechanical energy to usable electrical energy.
- Our team will also look at the business aspect of creating an efficient OWC and work with industry to develop a viable business plan based off our designs.

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