Design and Evaluation of a Two-Membrane Wave Energy Converter

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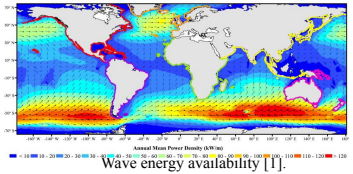
Motivation

Wave energy is abundantly available but underutilized. Compared with fossil fuels, ocean wave energy is cleaner with **lower emissions**. Each year 2.11 ± 0.05 TW of wave power are available globally, producing abundant opportunities to **expand global renewable energy** portfolio [1].



Wave energy availability [1].

Theory

Energy of an ideal ocean wave of amplitude A [2]:

$$E_{tot} = \frac{1}{2}\rho g A^2$$

Dynamic pressure at depth z:

$$p(z,t) = \underbrace{\rho g A \frac{\cosh[k(z+H)]}{\cosh(kH)}}_{P} \cos(\omega t)$$

The system was modelled as linear and second order:

$$m\ddot{x} + c\dot{x} + kx = P\cos(\omega t)$$

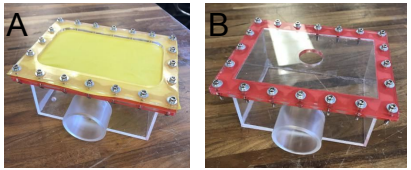
x – piston displacement
k – membrane elasticity
c – magnetic and viscous damping
m – total inertia (piston + moving water mass)
P – pressure wave amplitude

Project Goals

Problem: Commercially viable WECs have not been established; lack of scalability in current technology
Main goal: design and test a novel, scalable double membrane WEC system

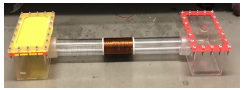
Experiment & System Design

System – Two acrylic boxes with flexible membrane tops, connected by tube. Magnetic piston in tube oscillates due to wave pressure fluctuations. Solenoid wrapped around the tube converts the mechanical energy of the magnet into electrical energy.



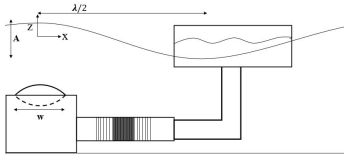
Boxes with (A) flexible and (B) rigid tops

To evaluate the benefit of the two membrane system, single membrane and double membrane configurations were tested inside a water tank under constant waves.

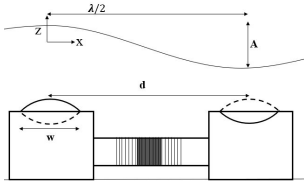


piston

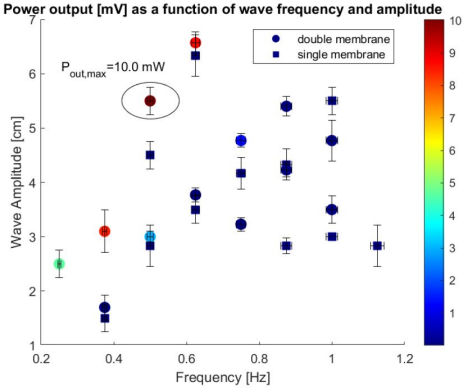
Single Membrane Case



Double Membrane Case



Results & Analysis



Power output (shown by color gradient) as a function of incident wave amplitude and frequency. Power output increased with amplitude, and attained its maximum value around 0.5Hz.

References

[1] Gunn K, Stock-Williams C. (2012). Quantifying the global wave power resource. Renew. Energy 44, 296–304. (doi:10.1016/j.renene.2012.01.101)
[2] Techet, A.H. *Hydrodynamics*. MIT, 2005.