Panagiotis Dafnakis (panagiotis.dafnakis@polito.it)
Advisor: Prof. Giuliana Mattiazzo
POLITECNICO DI TORINO

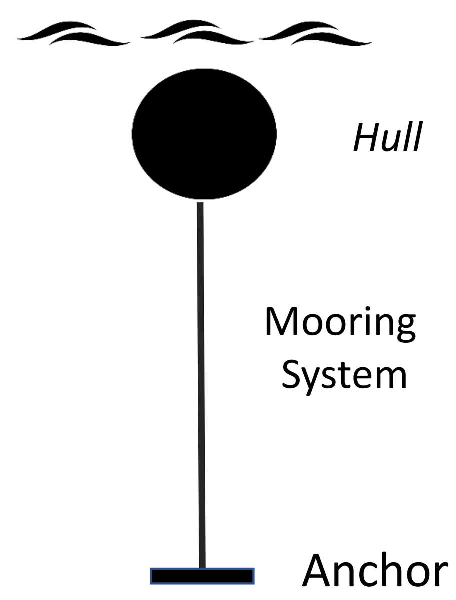
Numerical modelling and design of a submerged point absorber for the Mediterranean Sea

Design Process

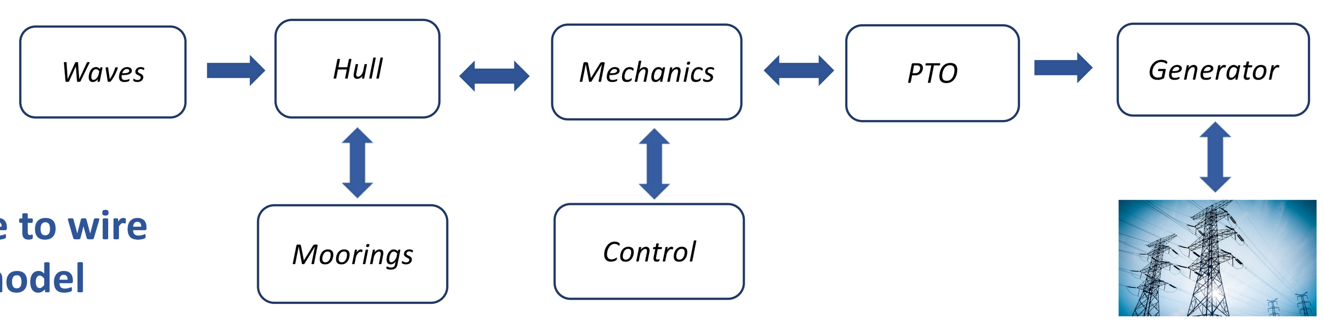
Technological concept

Submerged wave energy converter

- Waves create a pressure differential in the device
- Motion in multiple degrees of freedom
- Survival capacity in extreme conditions
- Non visible
- Adaptable in many sea states
- Minimal and simple design



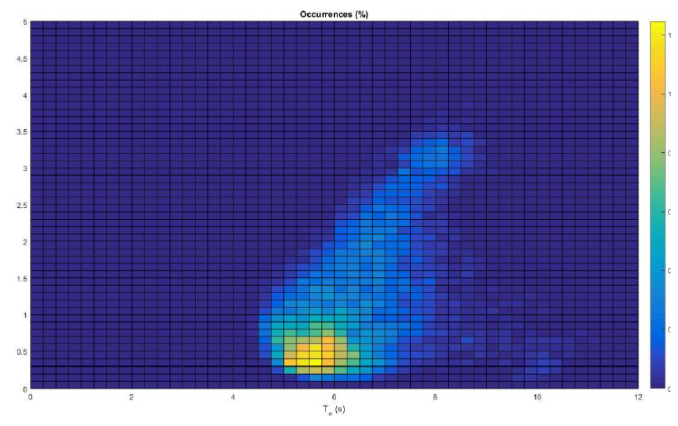
Schematic representation of the WEC



Wave to wire model

Design Process

Sea site - Pantelleria

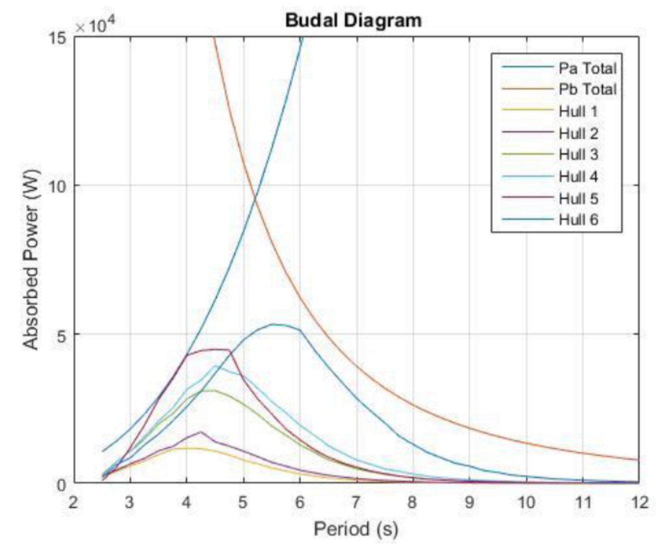


Wave scatter

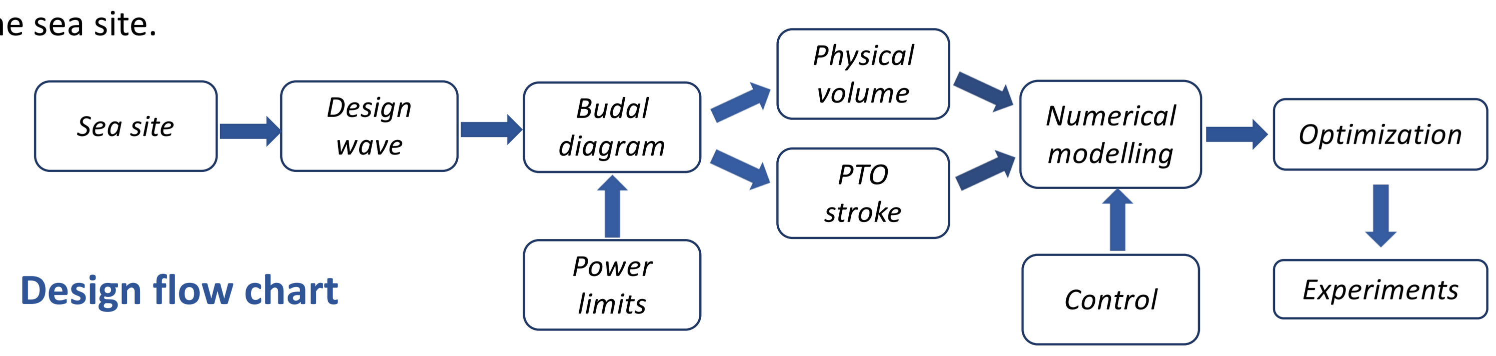
One of the most important characteristic of the point absorber function is the swept volume which is connected to the maximum stroke of the PTO system and as a result, influences the power productivity. It must be selected taking into account the available wave power of the sea site.

Budal Diagram

In Budal diagram the power absorption limits and the power productivity of devices with different swept volumes are demonstrated.



Budal diagram



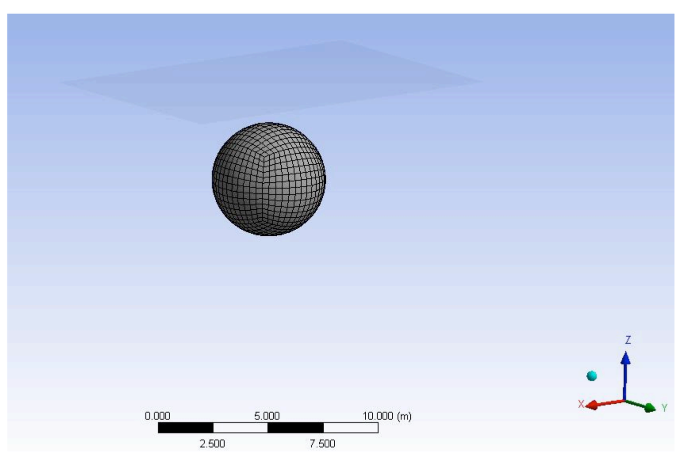
Design flow chart

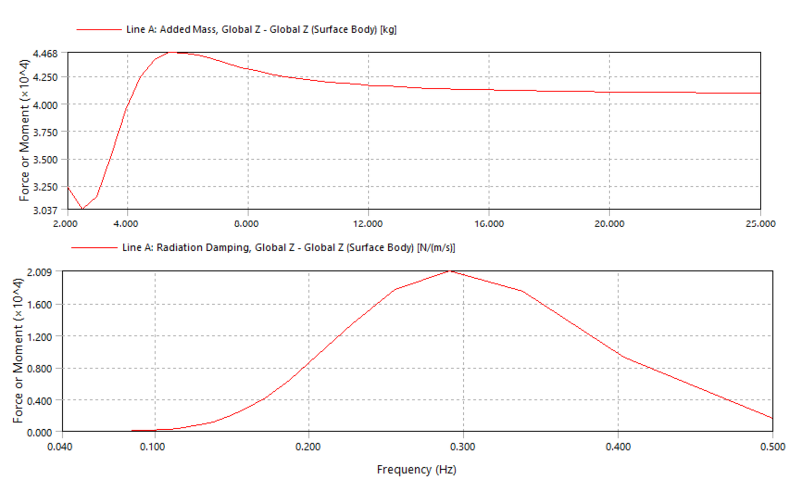
Numerical modelling

Potential flow based numerical model

Cummins Equation

$$(M + A_\infty)\ddot{x}(t) + \int_0^t K_r(t-\tau)\dot{X}(t)d\tau + F_m = F_e + F_{drag} + F_{pto} + F_H$$

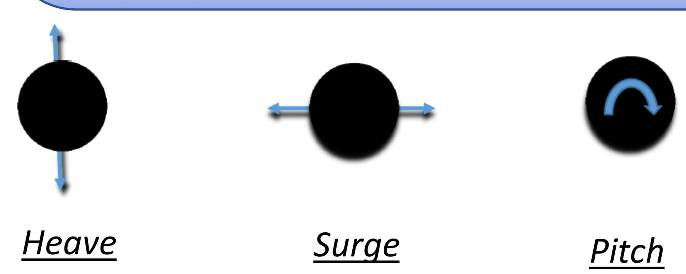




Potential flow based software Ansys AQWA

Characteristics

- Monochromatic/polichromatic wave analysis
- Linear PTO stiffness and PTO damping
- Three degrees of freedom: Surge, heave, pitch
- Various hull geometries



All the necessary hydrodynamic coefficients for the numerical modelling of the submerged point absorber have been obtained from the Boundary Element Method software Ansys AQWA. The frequency dependent added mass and radiation damping values of a spherical device are presented. The radius of the studied hull is 5.14 m and the center of mass is situated 4.53 m under the sea surface.

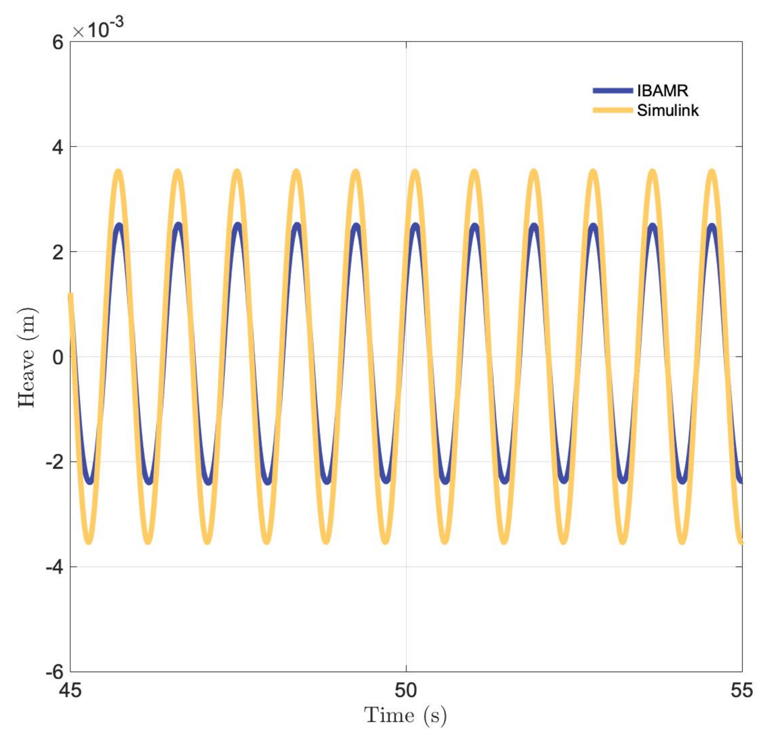
Wave structure interaction model - IBAMR

Equations of motion

$$\nabla \cdot u(x,t) = 0$$

$$\frac{\partial \rho u(x,t)}{\partial t} + \nabla \cdot \rho u(x,t)u(x,t) = -\nabla p(x,t) + \nabla \cdot [\mu(\nabla u(x,t) + \nabla u(x,t)^T)] + \rho g + f_c(x,t)$$

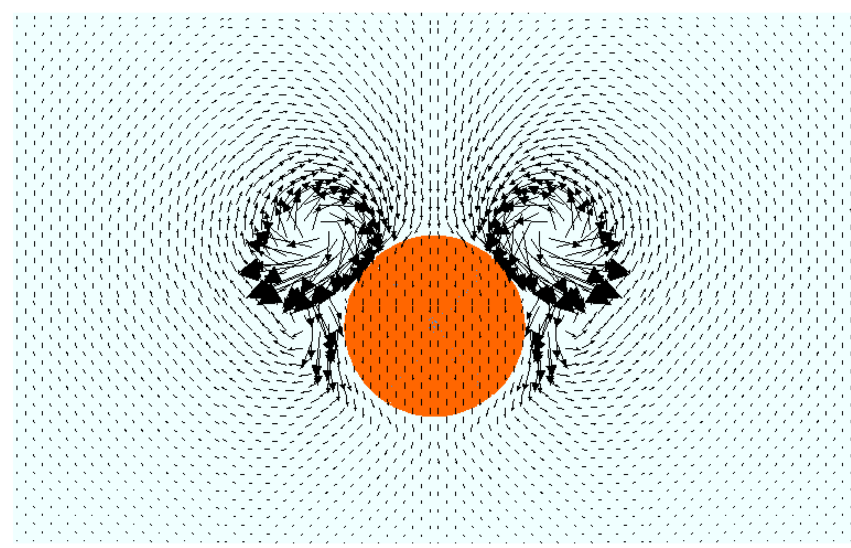
$$f_c(x,t) = \frac{\chi(x,t)}{K}(u_b(x,t) - u(x,t))$$



Model comparison

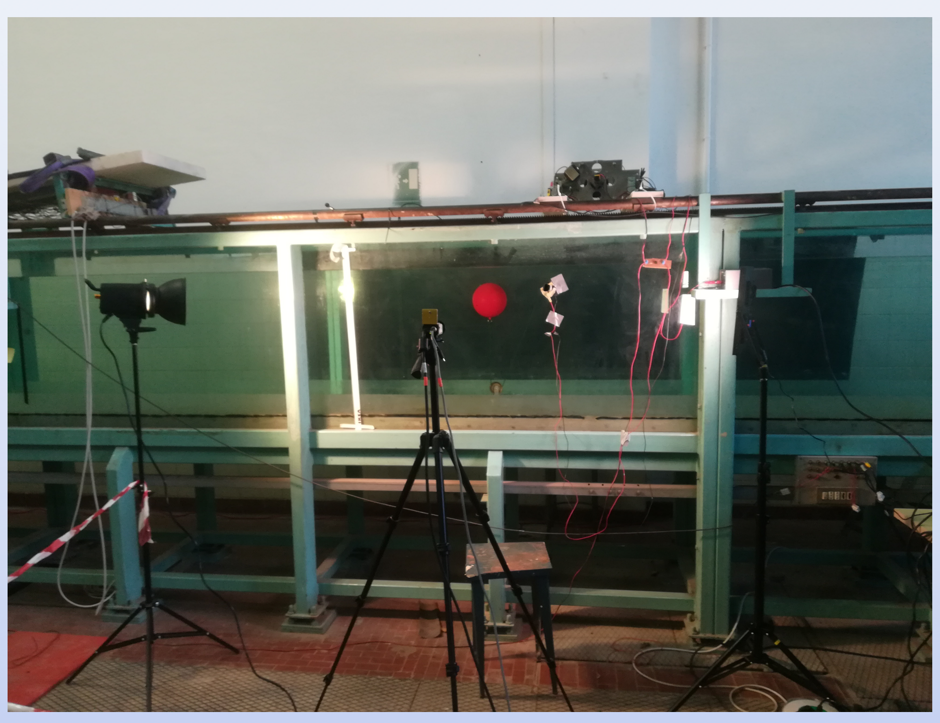
Characteristics

The wave structure interaction (WSI) model was built in the open-source library IBAMR. The main methodology for the numerical simulation is a fictitious domain strategy called Brinkman penalization. The equations for the coupled fluid structure interaction system are: 1) Continuity equation. 2) Incompressible Navier-Stokes momentum equation. 3) Costraint force equation. The WSI model has been developed in collaboration with San Diego State University.

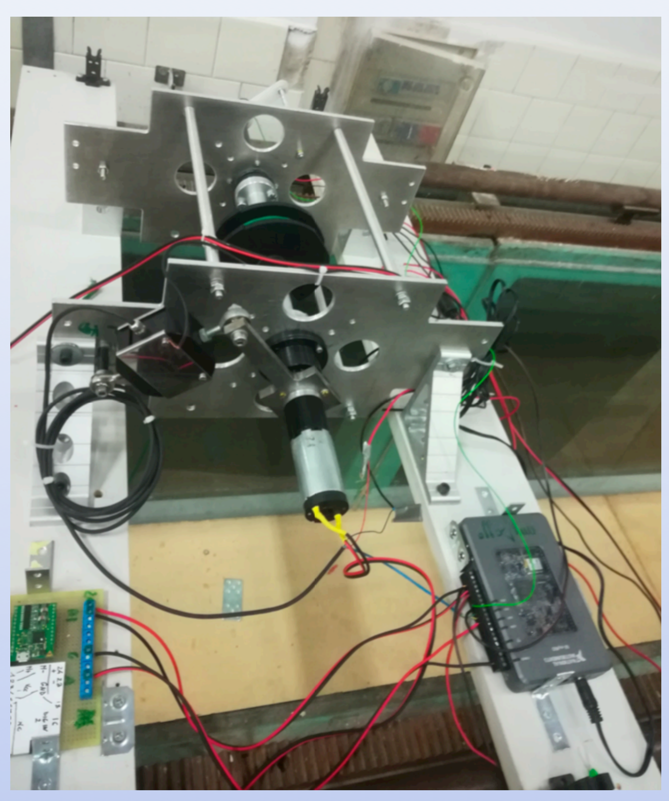


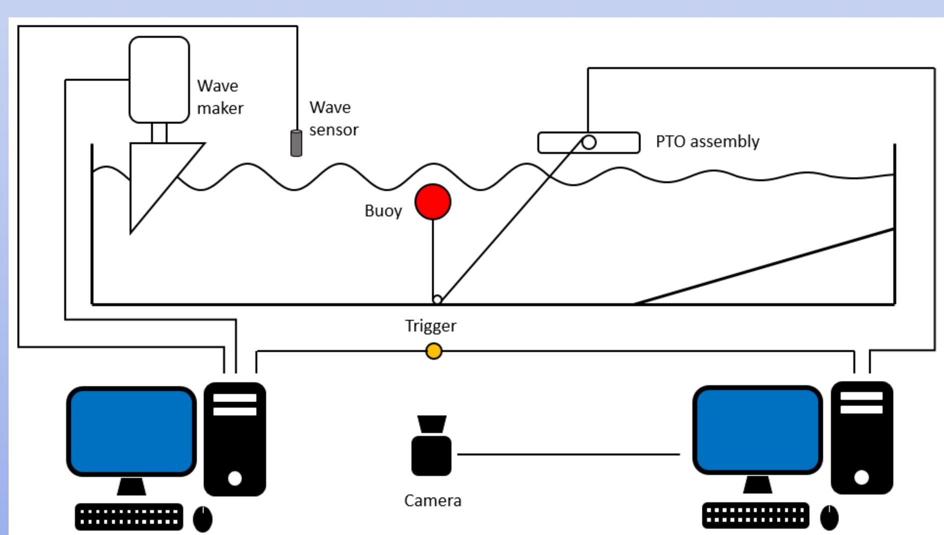
Velocity vector field in a WSI simulation

Experimental results and models validation

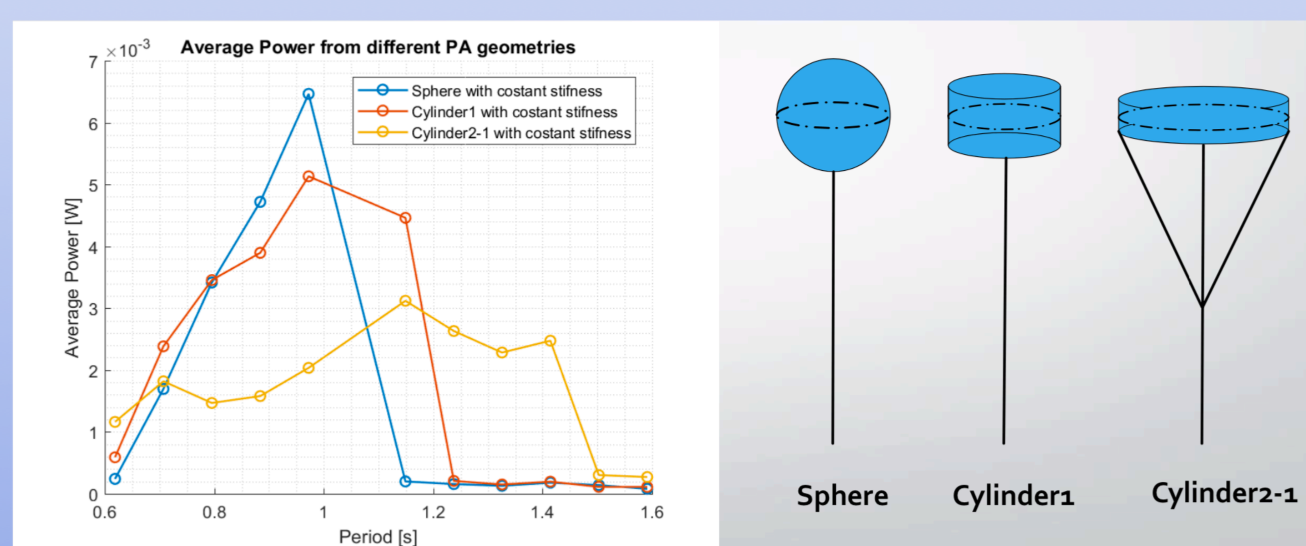


Experimental campaign in the wave flume in Politecnico di Torino. The small scale (1:32) prototype has diameter 16 cm and has been tested in regular waves. We obtain the motion of the device using motion tracking software and we control the dynamics of the point absorber by imposing different values of PTO stiffness and PTO damping. The purpose of the experiments was the validation of the numerical models and testing the hydrodynamic performance of the point absorber with different hull geometries and control strategies.

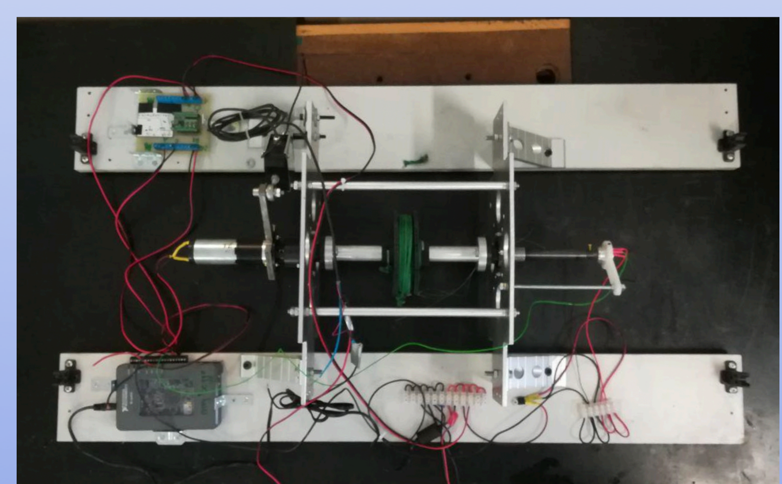




Experimental setup



Performance comparison



PTO prototype