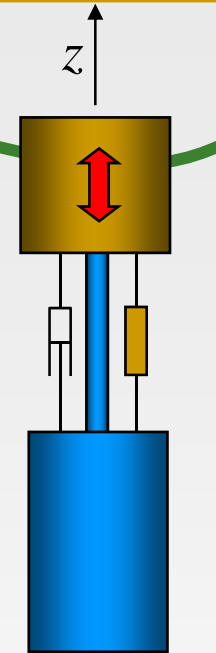


# Hydrodynamic Optimization of the Active Surface of a Heaving Point Absorber

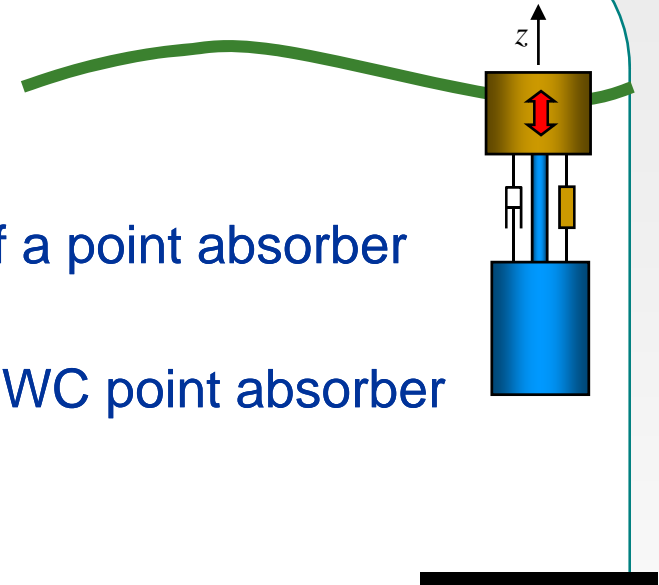


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António Sarmiento

# Summary

- Introduction
- Methodology to optimize the active surface of a point absorber
- Optimization of the overall dimension of an OWC point absorber
- Conclusions



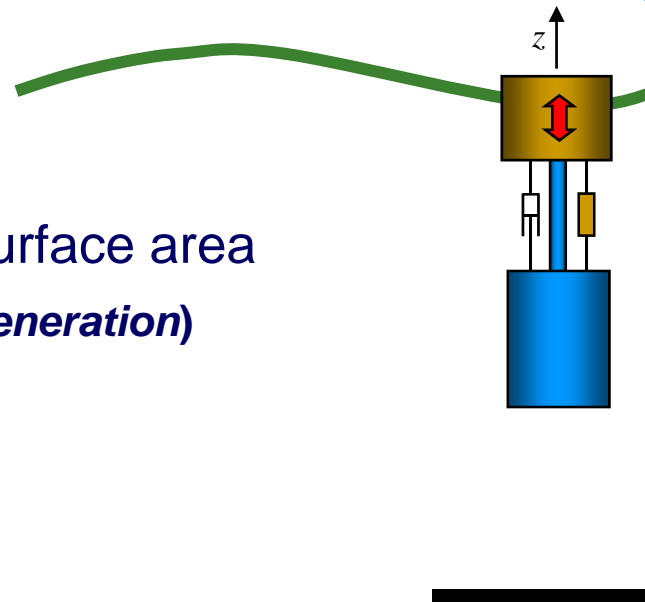
# Introduction

## ■ Objectives:

- Determination of the active surface area  
*(area responsible for the waves generation)*
- Entire Volume of the WEC

## ■ Assumptions:

- Linear wave theory
- Axissimetric point absorbers
- Sinusoidal waves
- Deep waters
- 1 DoF (heaving)



# Optimization of the Point Absorber Active Surface

## ACTIVE SURFACE DRAFT

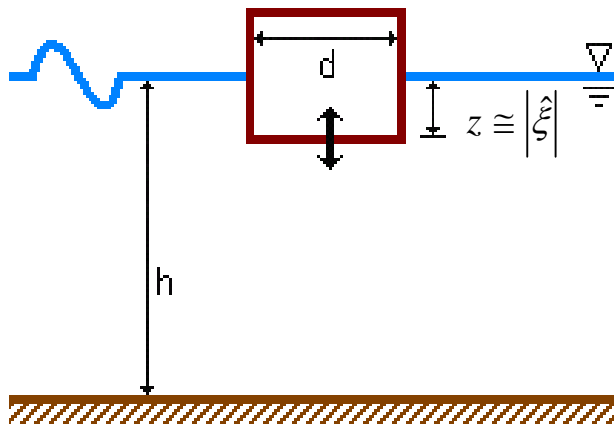
- Constant Hydrostatic Coefficient  
(*avoid slamming*)
- Velocity and Excitation Force in Phase



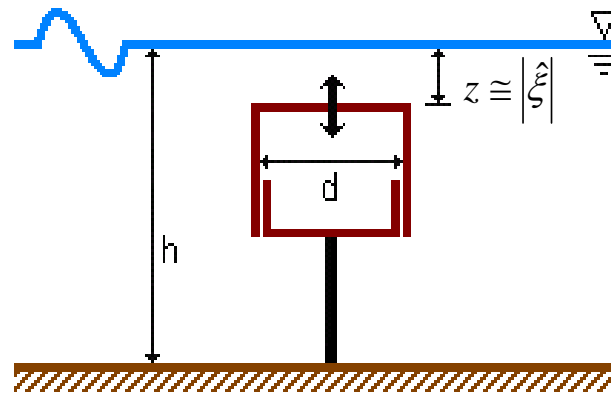
Heave Amplitude  
=  
Active Surface Draft

## MAXIMIZATION of the WEC RADIATION CAPABILITIES

Partially submerged heave WEC



Totally submerged heave WEC



# Optimization of the Point Absorber Active Surface

## DECOMPOSITION of the EXCITATION FORCE

$$\hat{F}_{ext} = \hat{F}_{FK} + \hat{F}_d = \underbrace{\left( A\rho gS - A\omega^2 m e^{-k|z|} \right)}_{\text{FROUD KRILOV}} \pm \underbrace{A(\omega^2 M - i\omega D)}_{\text{DIFFRACTION}} e^{-k|z|}$$

Totally submerged heave WEC

Partially submerged heave WEC

## SIMPLIFIED EXCITATION FORCE

$$\hat{F}_{ext}^* \cong \left( 1 \mp k|z| M^* \right) e^{-k|z|}$$

Dimensionless Excitation Force as a function of the added mass  $M$  and the active surface draft  $z$

### ASSUMPTION:

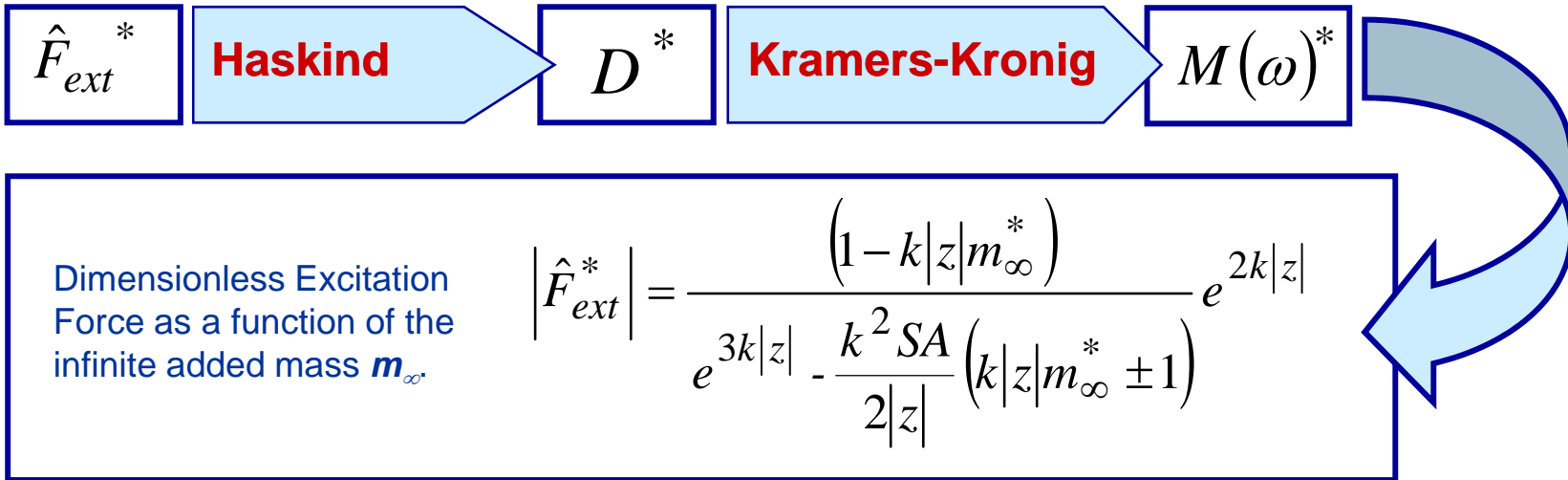
Impedance dominated by the reactive term

$$i\omega M \gg D$$



# Optimization of the Point Absorber Active Surface

## RESULTANT EXCITATION FORCE



## Kramers Kronig Relation

$$M(\omega) - m_\infty^* = \int_0^\infty \frac{D(y)}{\omega^2 - y^2} dy = \int_0^a \frac{D(y)}{\omega^2 - y^2} dy + \underbrace{\int_a^\infty \frac{D(y)}{\omega^2 - y^2} dy}_{=0}$$

### ASSUMPTION:

Neglected  $D(y)$  for  $y \gg a$  and  $z(a^2/g) < 1$



# Optimization of the Point Absorber Active Surface

## RADIATION POTENTIAL

$$\hat{\phi}_r = \underbrace{\hat{\phi}_{r_{nf}}}_{=0} + \hat{\phi}_{r_{ff}}$$

$$\hat{\phi}_r \approx C(\theta)e(kz)(kr)^{-1/2} e^{-ikr}$$

### **ASSUMPTION:**

Neglected near body radiated potential for long distances from the wave source.



## FAR FIELD COEFFICIENT

$$C = \frac{|A_r|g}{\omega} (kr)^{1/2} = \left( \frac{\omega k D}{\rho \pi} \right)^{1/2} |z|$$

### **ASSUMPTION:**

For deep waters and long distances from the wave source the far field coefficient, C, can be described as for a plan wave.



## EXCITATION FORCE for the DESIGN FREQUENCY

$$\left| \hat{F}_{ext}^* \right| = \frac{A}{|z|} \frac{1}{\pi (ka)^2}$$

### **ASSUMPTION:**

Optimal absorption condition, i.e, radiated power equal to the absorbed power

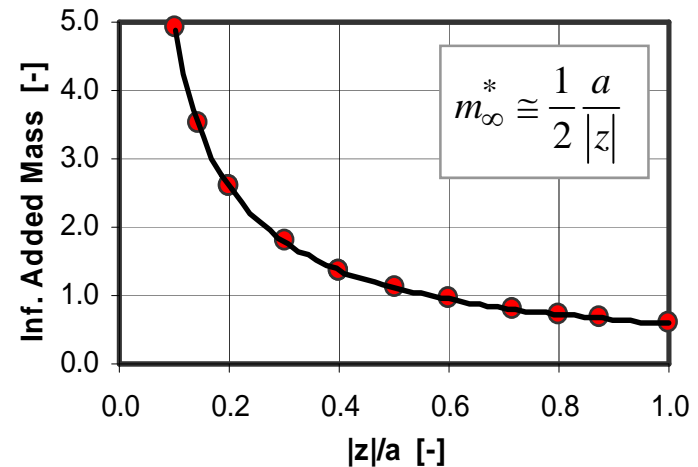


# Optimization of the Point Absorber Active Surface

Equalizing Both Excitation Force Expressions Results:

$$\frac{A}{|z|} \frac{1}{Sk^2} = \frac{(1 - k|z|m_{\infty}^*)}{e^{3k|z|} - \frac{k^2 SA}{2|z|} (k|z|m_{\infty}^* \pm 1)} e^{2k|z|}$$

Numerical Evaluation of the Infinity Added Mass



Non-dimensional relation between the optimal active surface radius,  $ka$ , relative draft,  $k|z|$ , and relative displacement amplitude,  $|z|/A$ .

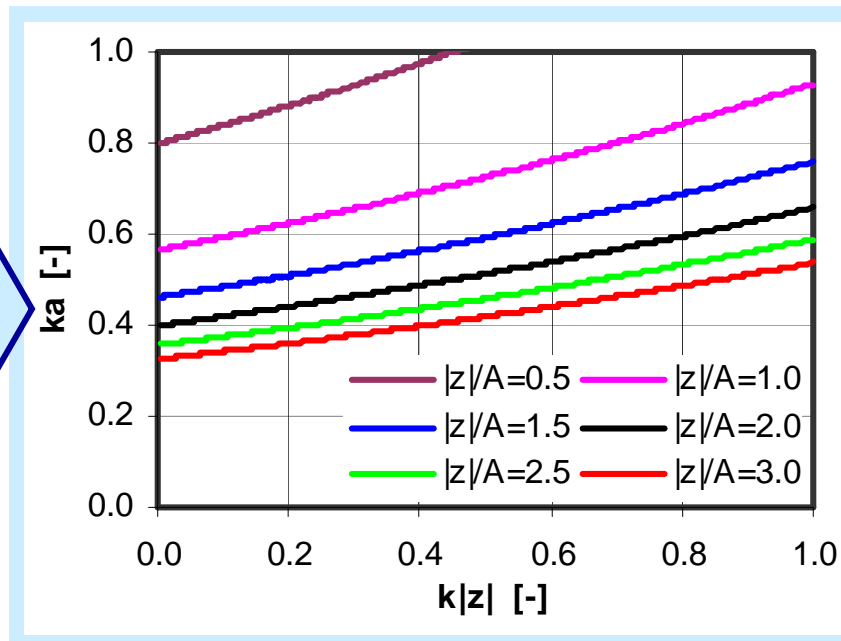
$$\frac{A}{|z|} \cong \pi (ka)^2 e^{-k|z|}$$



# Optimization of the Point Absorber Active Surface

Non-dimensional relation between the optimal active surface radius,  $ka$ , and relative depth,  $k|z|$ , for several relative displacements,  $|z|/A$ .

$$\frac{A}{|z|} \cong \pi(ka)^2 e^{-k|z|}$$

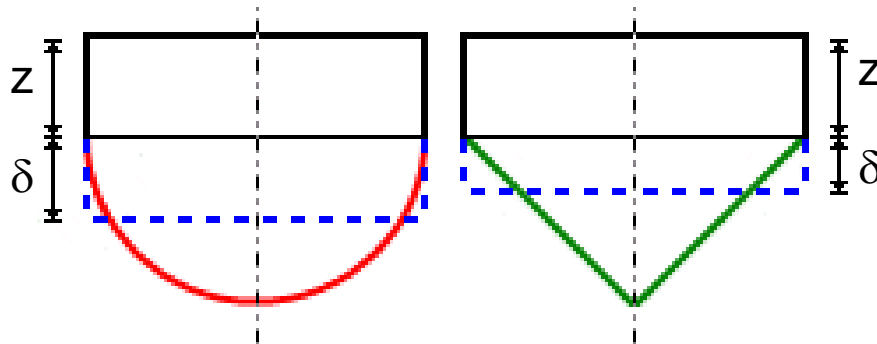


# Optimization of the Point Absorber Active Surface

## REDUCTION OF THE VISCOUS EFFECTS

### Methodology:

Non-linear evaluation of several bottom shapes to identify the one which reduces the viscous dissipation and also minimizes the increment,  $\underline{\Omega}$ , of the dynamic pressure centre



Potential WEC bottom shapes for the reduction of viscous effects (red or green)

Respective flat bottoms at identical depth of the dynamic pressure centre (blue).

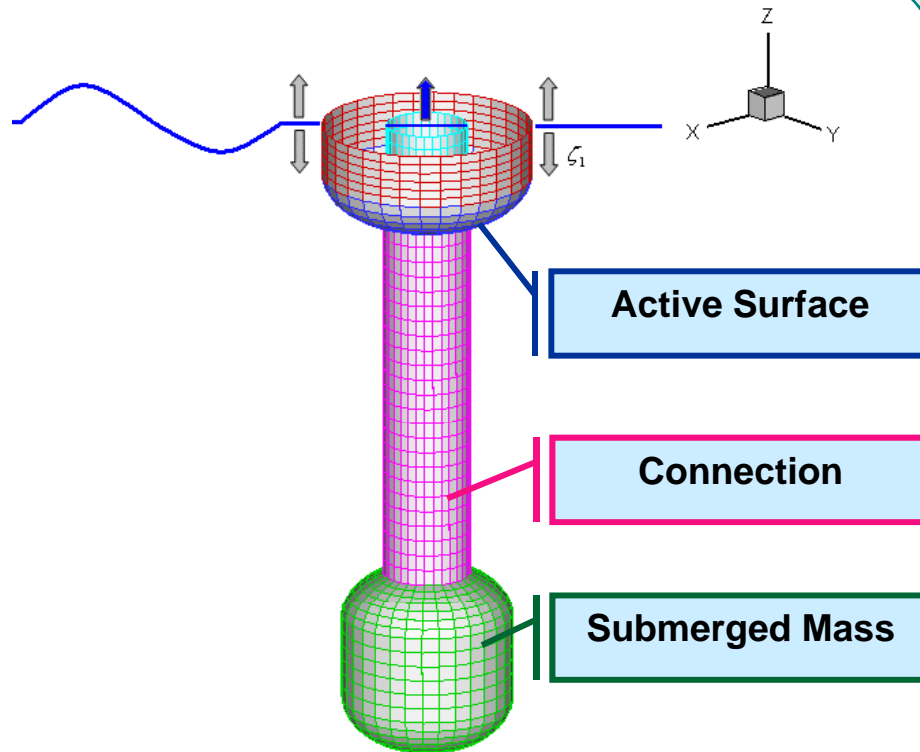
$$\frac{A}{|z|} \cong \pi(ka)^2 e^{-k|z+\delta|}$$

Non-dimensional relation slightly modified to take into account the additional depth of the dynamic pressure centre,  $\underline{\Omega}$ .

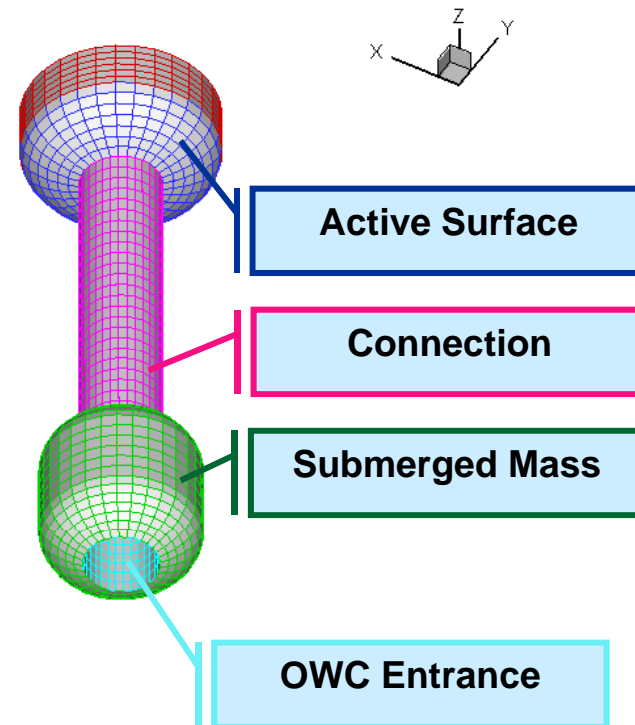


# OWC WEC Under Evaluation

LATERAL VIEW



BOTTOM VIEW



Discretization of the OWC Wet Surface



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## ***Conclusions***

### **Active Surface:**

It seems to be possible to define the active surface of an heaving point absorber to maximize the energy absorption.

### **Entire Volume:**

The entire volume of the device should be defined according to the area of the active surface adding a submerged mass located deep enough not to affect significantly the optimized radiation capabilities of the device.

