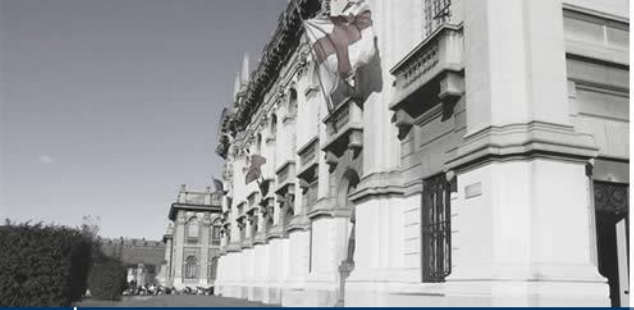

EERA DeepWind'2015

12th Deep Sea Offshore Wind R&D Conference

POLITECNICO DI MILANO

Study of the effect of water depth on potential flow solution of the OC4 Semisubmersible Floating Offshore Wind Turbine

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Structure of the presentation

1. Introduction and motivation of this work
2. Modelling approach
    1. Potential Flow Solution
    2. Shallow water waves
3. Preliminary considerations (dispersive waves)
4. Results
5. Conclusions

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Wind System:

OC4 – IEA Task 30 – Phase II :
Floating Semisusbmersible

Water depth: 200m
Draft: 20 m

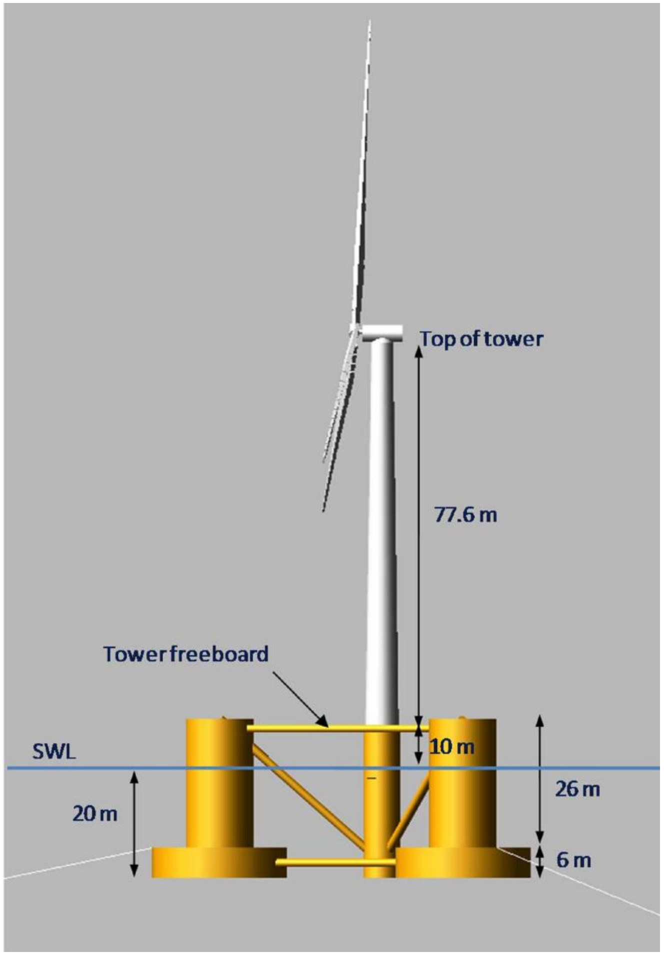
Main questions:

What if we considered lower water depth for this system?

How is the potential flow affected?

Reference state of art:

Studies on the hydrodynamics of Liquified Natural Gas Carriers (LNGC) in shallow waters



Modelling approach: potential flow

Computational Tools (MARIN):

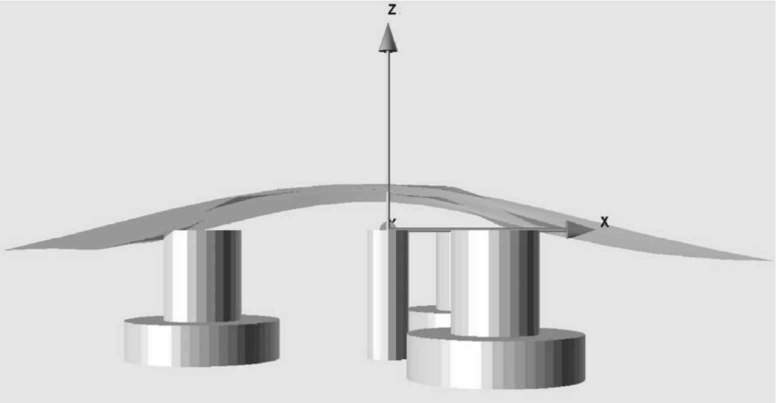
DIFFRAC: 3D panel-based solver
aNySIM: Time domain analysis of FOWT

Hydrodynamics:

First order:
Added Mass, Damping, Wave Excitation Forces

Second order:
Quadratic Transfer Functions QTFs

Pinkster approximation of the second order velocity potential



Degrees of Freedom investigated:

Surge, Heave, Pitch

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Shallow water: setdown effect

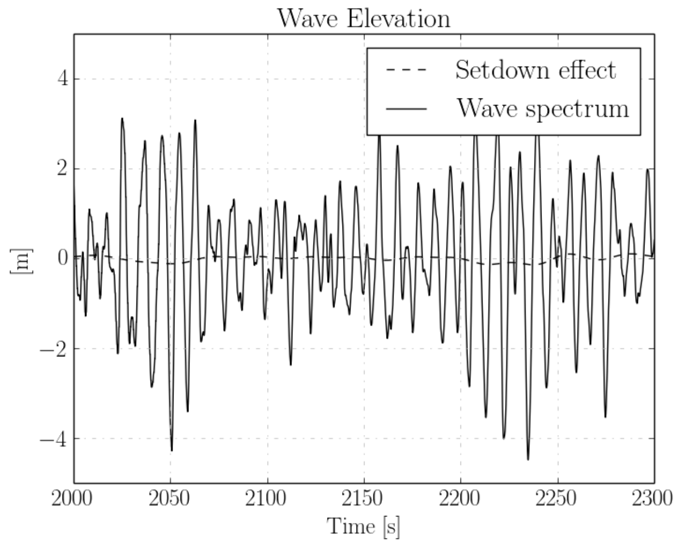
- Long waves bound to short waves

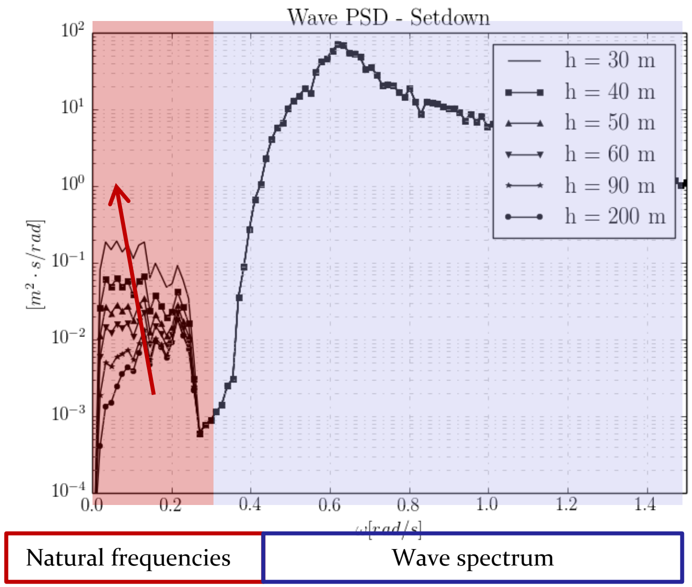
$$\xi = \xi^{(1)} + \xi^{(2)} =$$

$$= \sum_{i=1}^{N} a_i cos(\omega_i t + \epsilon_i) + \sum_{i=1}^{N} \sum_{j=1}^{N} a_i a_j D(\omega_i, \omega_j, k_i, k_j) cos((\omega_i - \omega_j)t + \epsilon_i - \epsilon_j)$$

- System's natural frequency range (+ difference frequency QTFs)

- The less water depth, the more setdown effect



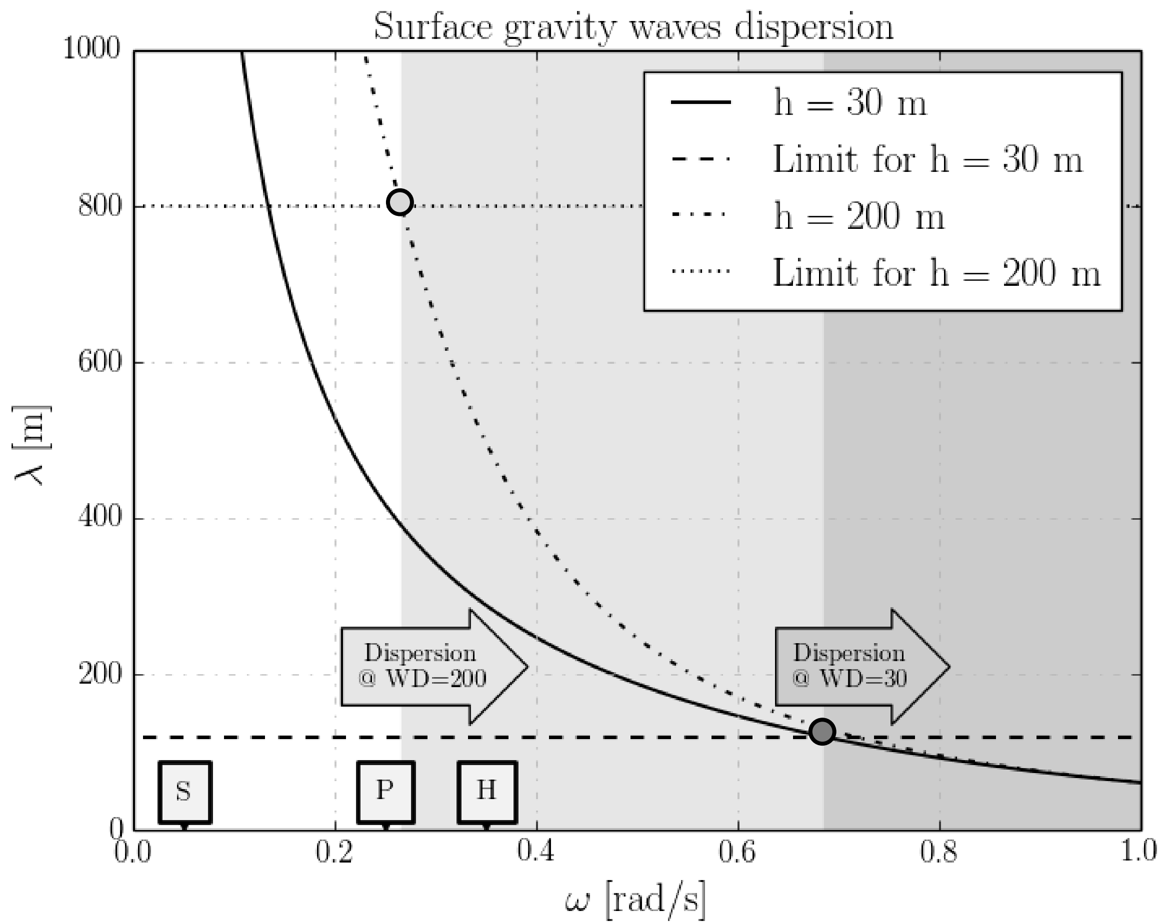


Dispersion relation:

$$\omega(k) = \sqrt{g \cdot k \cdot tanh(kh)}$$

Dispersion limit:

$$\lambda = 4h$$



<u>As the water depth varies…</u>

- Heave is expected to be affected the most
- Above 1-1.2 rad/s no difference is expected

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Results: statistics of the response

OC4 – Load Case 2.2

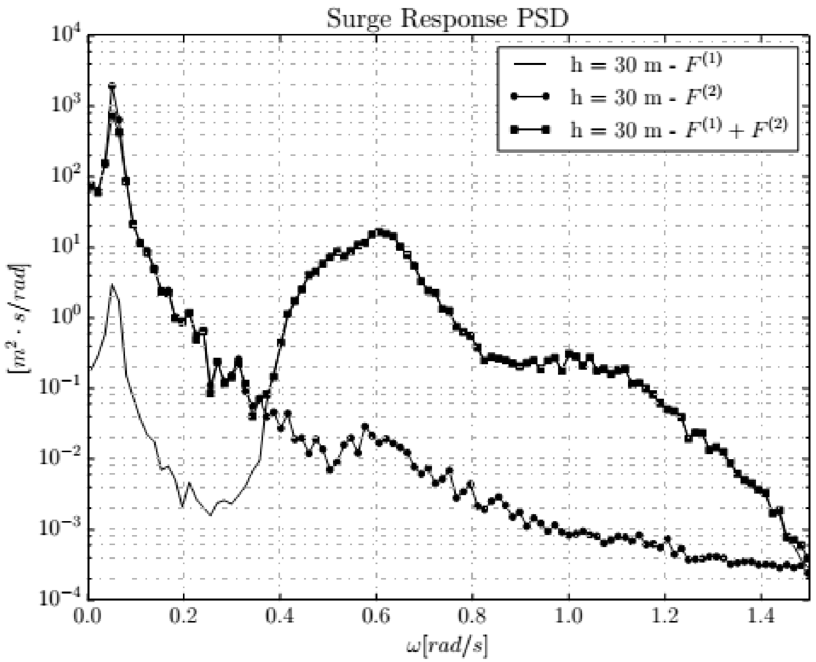
Load case ($F^1 + F^2$)	Type	Surge Mean [m]	Surge Standard Deviation [m]	Heave Mean [m]	Heave Standard Deviation [m]	Pitch Mean [deg]	Pitch Standard Deviation [deg]
h = 30 m	No Setdown	1.75	2.017	0.031	0.183	0.006	0.584
	Setdown	1.802	2.616	0.031	0.205	0.006	0.556
h = 40 m	No Setdown	1.473	1.514	0.032	0.203	0.027	0.619
	Setdown	1.495	1.769	0.032	0.207	0.026	0.603
h = 50 m	No Setdown	1.396	1.405	0.031	0.227	0.032	0.647
	Setdown	1.409	1.507	0.031	0.228	0.032	0.636
h = 60 m	No Setdown	1.371	1.358	0.030	0.246	0.034	0.663
	Setdown	1.380	1.412	0.030	0.246	0.034	0.653
h = 200 m	No Setdown	1.371	1.334	0.030	0.275	0.036	0.682
	Set Down	1.373	1.338	0.030	0.274	0.036	0.677

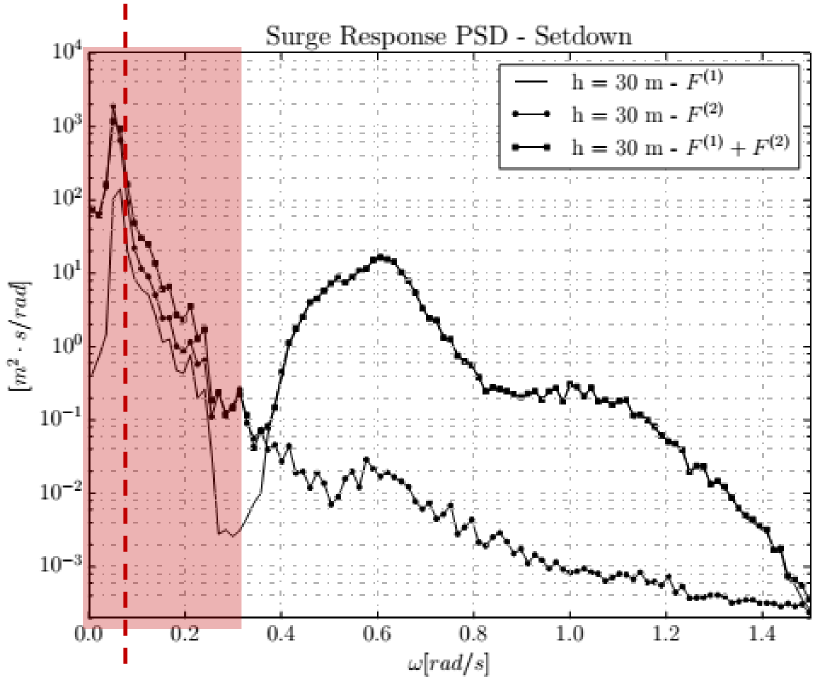
Setdown effect plays an important role on **Surge**

Water depth plays an important role on **Heave**

Results: Power Spectral Densities

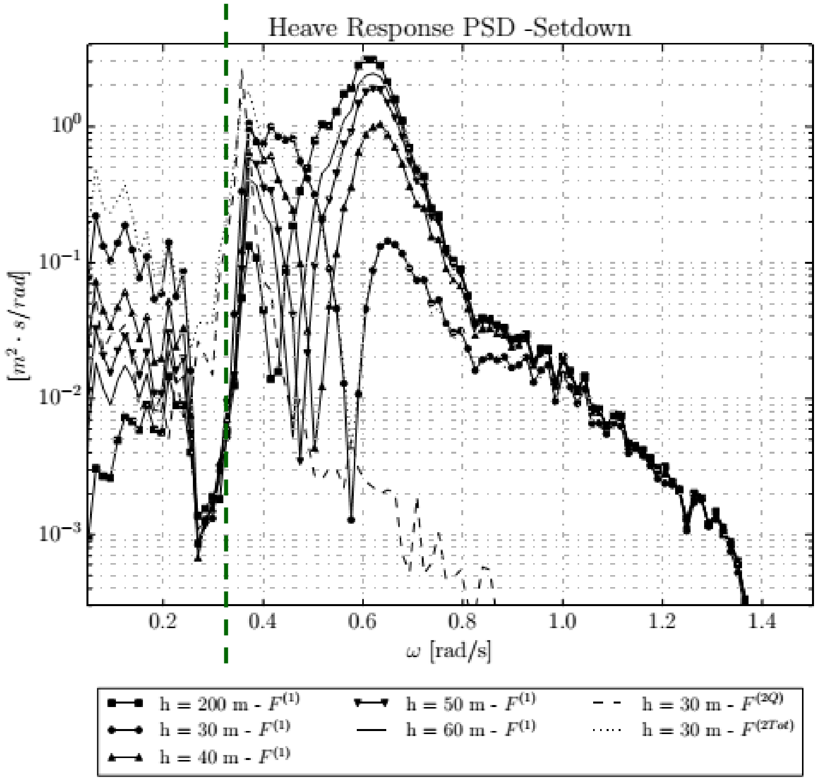
Setdown effect plays an important role on **Surge**

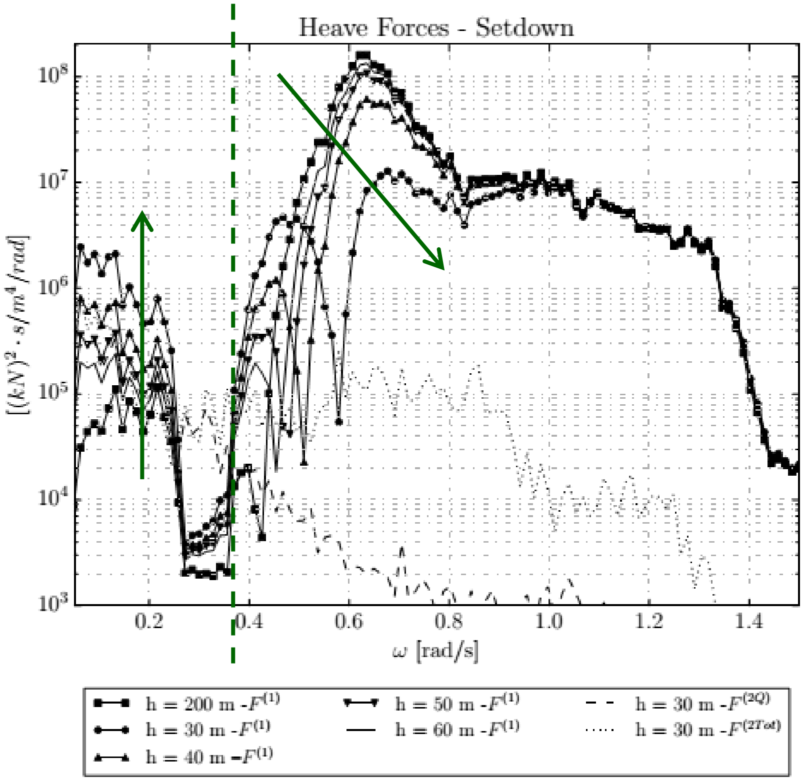


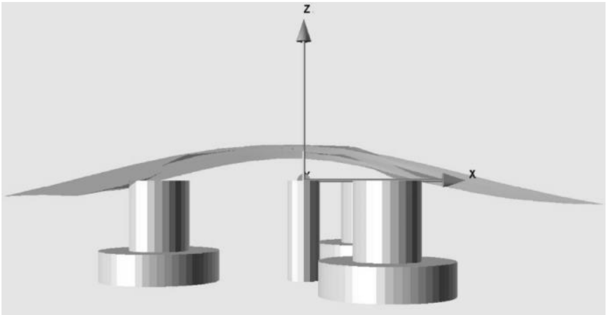


(Setdown wave + 1° Order hydrodynamics)
+
Difference QTFs (2° order hydrodynamics)

Water depth plays an important role on **Heave**







Moving to shallow waters the Semi cylinders are not excited in phase in the wave frequency range

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Conclusions

1. OC4-Semi Heave natural frequency for shallow water (30 m) cannot be seen as “dispersive” as for deep water (200 m)

2. Setdown effect plays an important role on Surge $\uparrow$

3. Water depth plays a important role on Heave $\downarrow$

4. Surge less influenced by water depth as expected (LNGC):

   (OC4-Semi more transparent to waves)

5. Heave more affected by water depth, although influence is little.

Thank you!

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Simulations set-up

Load Case:

OC4-L.C.2.2

Jonswap Spectrum: Hs = 6m, Tp = 10s

Simulation time:

Total simulation – 4500 s

Start-off statistic – 1000 s (regime)

Sampling time – 0.1 s

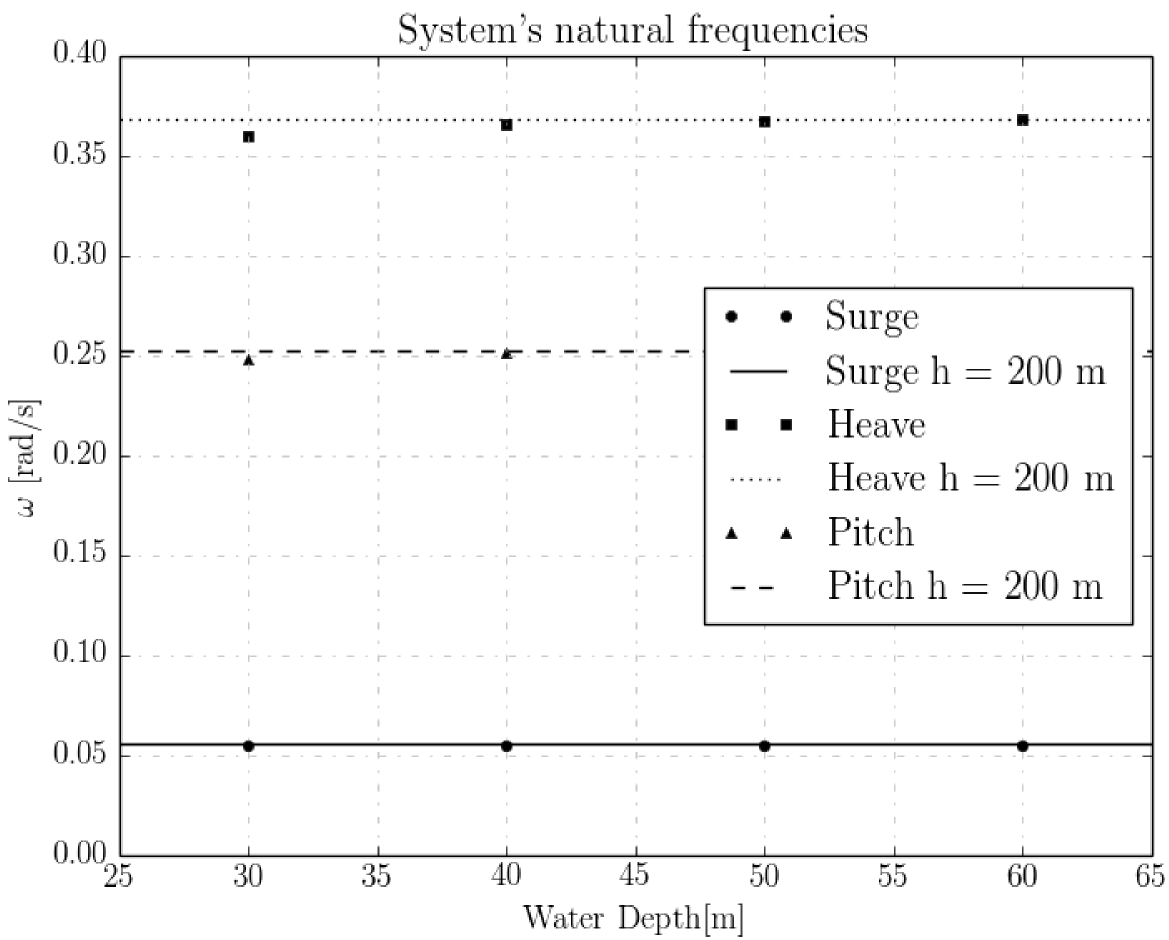
Viscous damping:

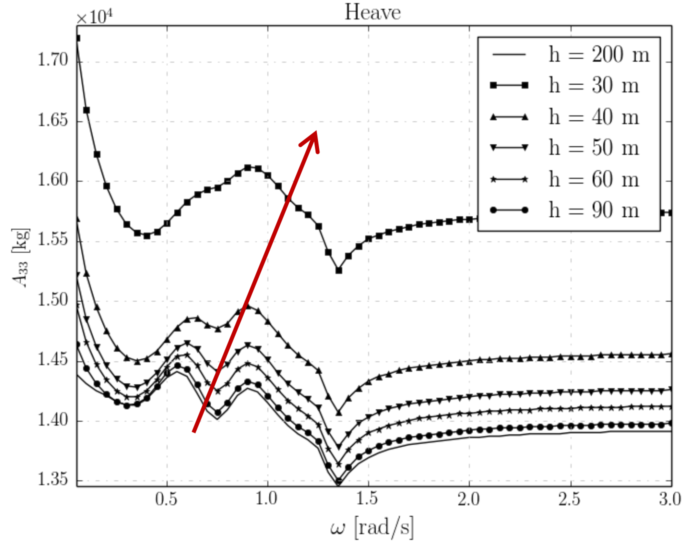
Constant (OC4)

Contributions:

- First order forces
- Second order forces (Pinkster)
  - Quadratic contribution (I-IV)
  - Total Contribution (I-V)
- Incoming wave train with setdown effect

Natural frequencies





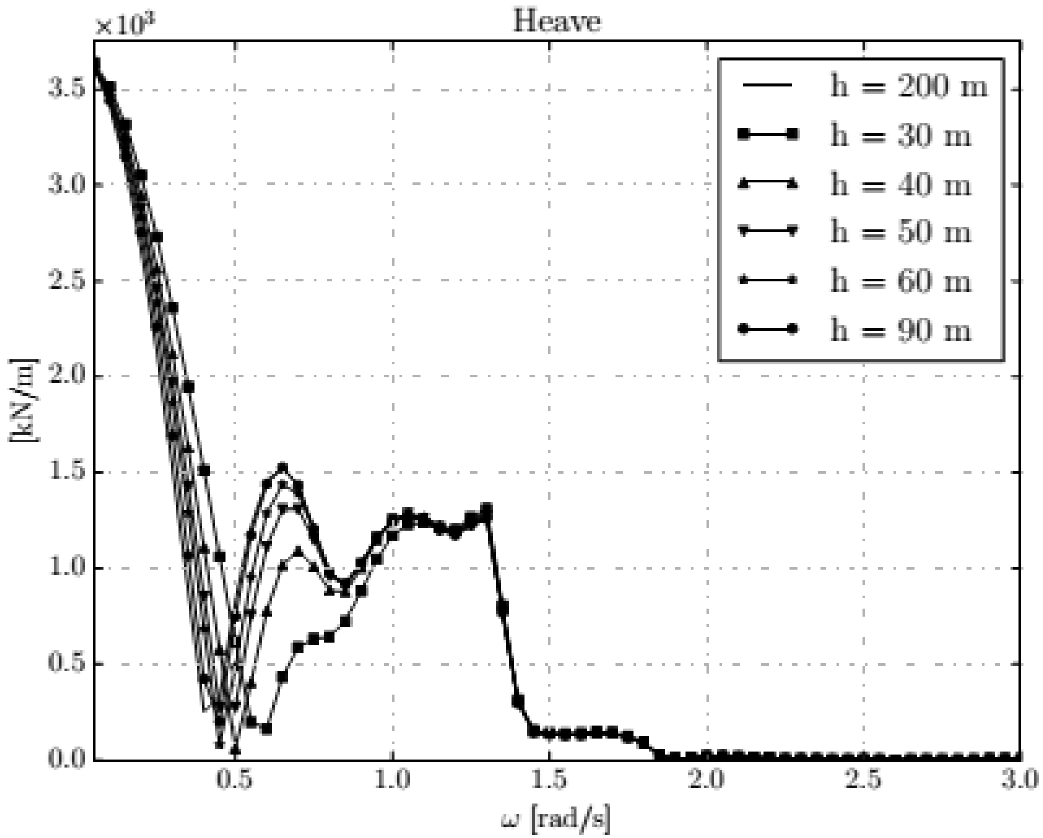
Second order forces: Pinkster approx.

$$\overrightarrow{F}^{(2)} = \overrightarrow{F}^{(2)}_{I} + \overrightarrow{F}^{(2)}_{II} + \overrightarrow{F}^{(2)}_{III} + \overrightarrow{F}^{(2)}_{IV} + \overrightarrow{F}^{(2)}_{V}$$

$$= -\frac{1}{2}\rho g \int_{WL} \xi^{2}_{(1),rel} \cdot \overrightarrow{n}_0 \cdot \overrightarrow{dl} + \frac{1}{2}\rho \iint_S \nabla\Phi_{(1)} \cdot \nabla\Phi_{(1)} \cdot \overrightarrow{n}_0 \cdot dS +$$

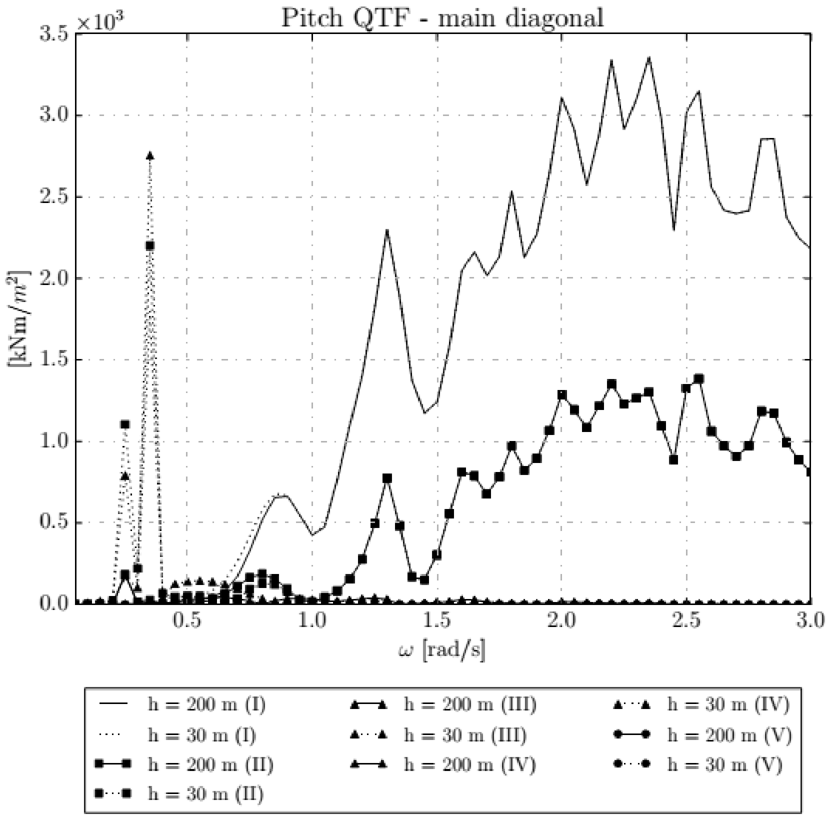
$$\iint_S \rho \cdot X_{(1)} \cdot \nabla \frac{\partial \Phi}{\partial t} \cdot \overrightarrow{n}_0 \cdot dS + \overrightarrow{\Omega}_{(1)} \times M \ddot{\overrightarrow{X}}_{(1)} + \rho \iint \frac{\partial \Phi_{(2)}}{\partial t} \cdot \overrightarrow{n}_0 \cdot dS$$

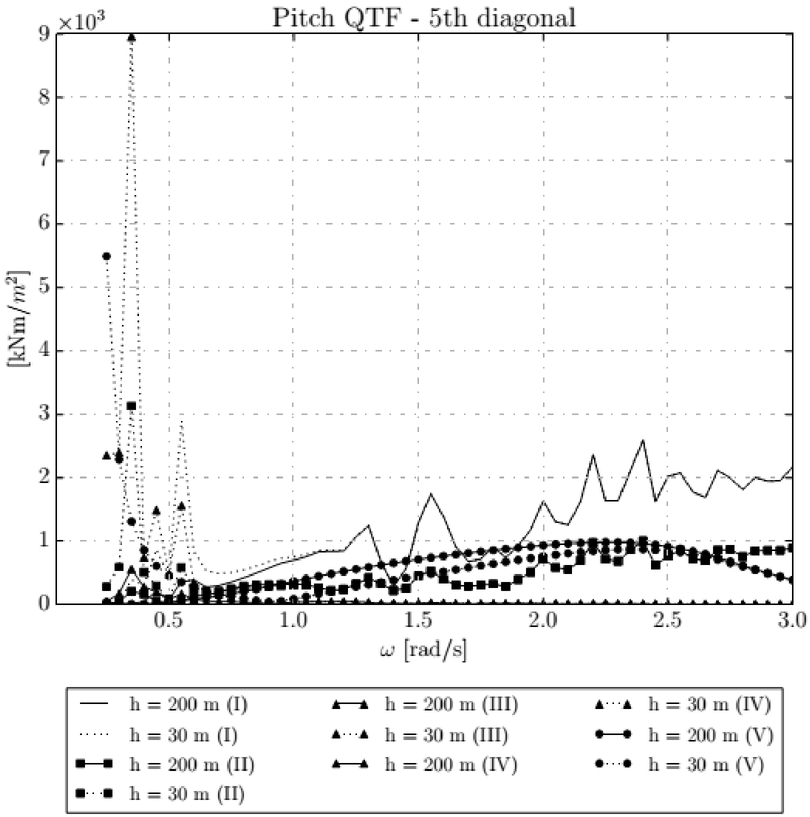
Potential solution for $\omega > 1\ rad/s$



Potential solution for $\omega > 1\ rad/s$

2/2





Heave affected by change in wd

2/2