TÉCNICO LISBOA

Wave generation, stability of floating bodies and test of an offshore wind platform

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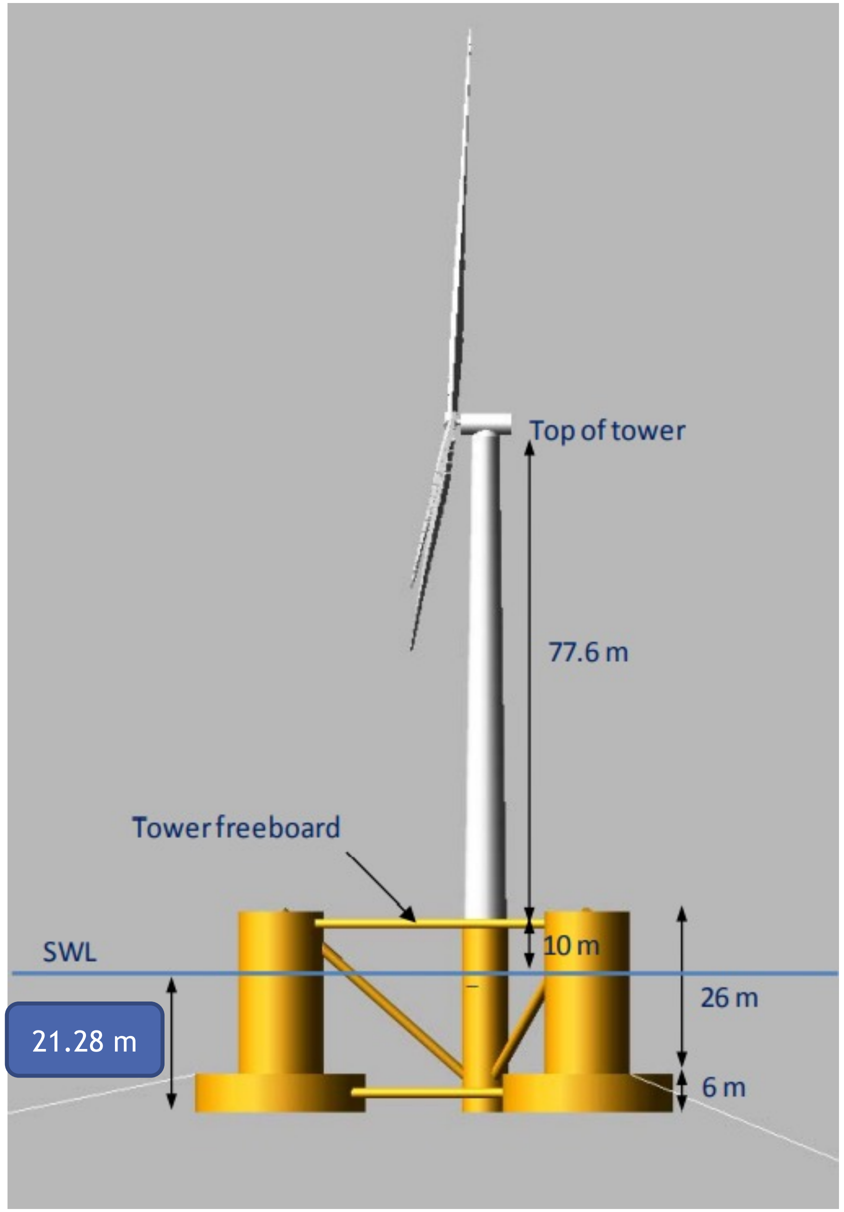


INTRODUCTION

- The scope of the laboratory activity is to obtain the values of different Response Amplitude Operator (RAO) by means of three different methods
- The RAO represents the ratio of the response of the amplitude normalised by the wave amplitude

INTRODUCTION

- The dimensional analysis is necessary to achieve accurate models to study the dynamics of an offshore wind platform. The use of scaled physical models is important in order to replicate the physical phenomena that appears in a full-scale prototype
- It is necessary to verify geometric, kinematic and finally dynamic similarity

Property	Dimensions	Scaling factor
Length	L	ϵ
Wave height	L	ϵ
Water depth	L	ϵ
Displacement	L	ϵ
Velocity	LT^{-1}	$\epsilon^{1/2}$
Acceleration	LT^{-2}	1
Time	T	$\epsilon^{1/2}$
Wave period	T	$\epsilon^{1/2}$
Wave frequency	T^{-1}	$\epsilon^{-1/2}$
Angle	–	1
Mass	M	$(\varrho_p/\varrho_m)\epsilon^3$
Moment of inertia	ML^2	$(\varrho_p/\varrho_m)\epsilon^5$
Moment of area	L^4	ϵ^4
Force	MLT^{-2}	$(\varrho_p/\varrho_m)\epsilon^3$
Moment	ML^2T^{-2}	$(\varrho_p/\varrho_m)\epsilon^4$
Pressure	$ML^{-1}T^{-2}$	$(\varrho_p/\varrho_m)\epsilon$
Power	ML^2T^{-3}	$(\varrho_p/\varrho_m)\epsilon^{7/2}$

METACENTRIC HEIGHT

1. THEORETICAL METACENTRIC HEIGHT

$$GM = KB + BM - KG$$

- KB is the distance between the keel of the platform and the center of buoyancy

$$KB = \frac{\sum z_i V_i}{\nabla}$$

- BM is the distance between the center of buoyancy and the metacenter of the platform

$$BM = \frac{I}{\nabla}$$

- KG is the distance between the keel and the center of gravity, computed from the one of the model using dimensional analysis

METACENTRIC HEIGHT

2. EXPERIMENTAL METACENTRIC HEIGHT

The objective of the experimental procedure is to change the centre of mass of the floating body and observe its influence on the stability of the barge, for this purpose a barge equipped with a vertically movable weight was used in the lab

$$GM = \frac{m_j}{m_F + m_j} \frac{dx}{d\theta} \text{ [m]}$$

Where:

- m_j is the jockey's mass
- m_F is the model's mass
- δx is the distance between central column and m_j
- $\delta\theta$ is the tilt angle

From the experimental metacentric height of the model we can obtain the one of the prototype with dimensional analysis:

$$GM_{prototype} = GM_{model} \cdot \epsilon$$

RAO ESTIMATION FROM WaMIT

- The data necessary to compute the RAO with this method was acquired from the report NREL/TP-5000-60601, in particular it has been used to obtain the added mass, damping coefficient and the hydrodynamic wave excitation as function of the frequency.

$$RAO_{33}(\omega) = \frac{X}{\zeta_a} = \frac{\frac{F_0(\omega)}{\zeta_a}}{\sqrt{\left(C_{33}-\left(M+A_{33}(\omega)\right)\omega^2\right)^2+\left(B_{33}(\omega)\omega\right)^2}}\,[-]$$

$$RAO_{55}(\omega) = \frac{\theta}{\zeta_a} = \frac{\frac{M_0(\omega)}{\zeta_a}}{\sqrt{\left(C_{55}-\left(J_{yy}+A_{55}(\omega)\right)\omega^2\right)^2+\left(B_{55}(\omega)\omega\right)^2}}\left[\frac{\circ}{m}\right]$$

- The second step is then to evaluate the spring constants C_{33} and C_{55} for heave and pitch, from the theory we know that they can be computed as:

$$C_{33} = \rho \cdot g \cdot A_w \left[\frac{N}{m}\right]$$

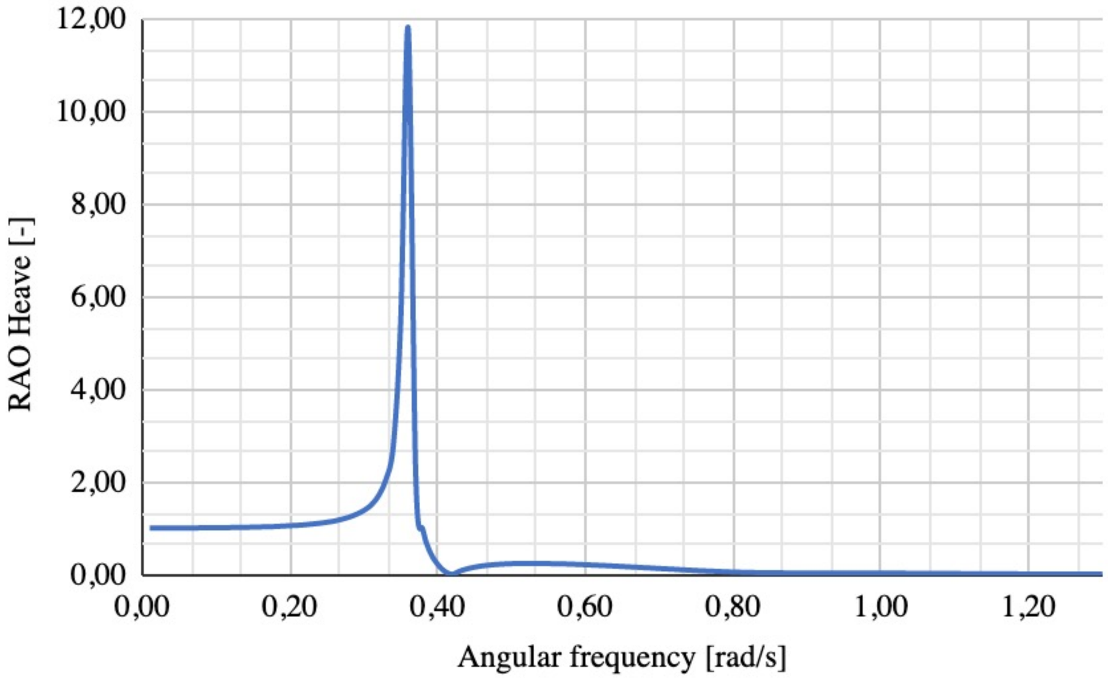
$$C_{55} = \rho \cdot g \cdot \nabla \cdot GM\,[N \cdot m]$$

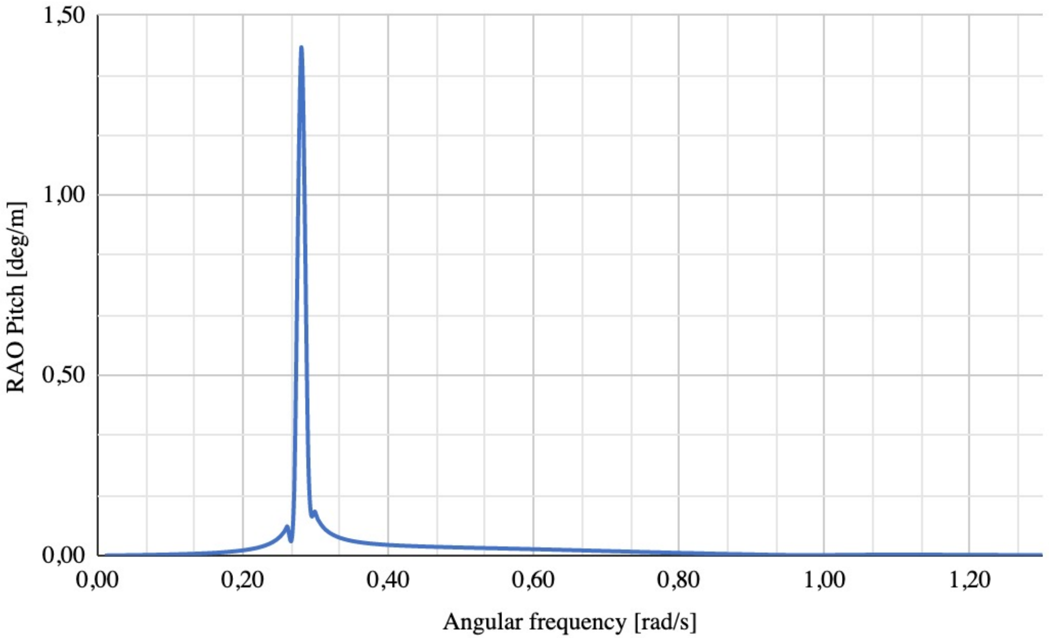
- The parameters that vary with the frequency have been acquired from the given excel file

RAO ESTIMATION FROM WaMIT

Important considerations are:

- When the wave frequency tends to zero, the RAO for heave tends to one and the one for pitch tends to zero, this is a confirmation of the theoretical value that we obtain when performing the limit
- When the frequency of the waves increases, the wavelength decreases, the platform will experience at the same time more than one wave excitation, this causes the heave and pitch RAOs to tend to zero with the increase of the wave frequency





RAO ESTIMATION FROM DECAY TEST

- In order to determine the natural characteristics of the oscillatory behaviour of the platform, such as: added mass (heave), added inertia (pitch), damping constant and spring constant, free-decay tests have been conducted
- Three heave motion decay tests were conducted, we choose the third test as it is maintained for the longest
- Five pitch motion decay tests were conducted during the analysis. In order to conduct further calculations, the second test was chosen, as it is maintained for the longest
- Damping coefficient and motion period for every step were calculated for both of the tests using the equations:

$$\xi_i = \frac{ln(\frac{x_i(t)}{x_i(t+T)})}{2\pi} \; [-]$$

$$T = t_f - t_i \; [s]$$

RAO ESTIMATION FROM DECAY TEST

- Average damping frequency and average natural frequency were calculated for the tested model using equations presented below:

$$\omega_d = \frac{2\pi}{\bar{T}} \left[\frac{rad}{s}\right]$$

$$\omega_n = \frac{\omega_d}{\sqrt{1-\xi^2}} \left[\frac{rad}{s}\right]$$

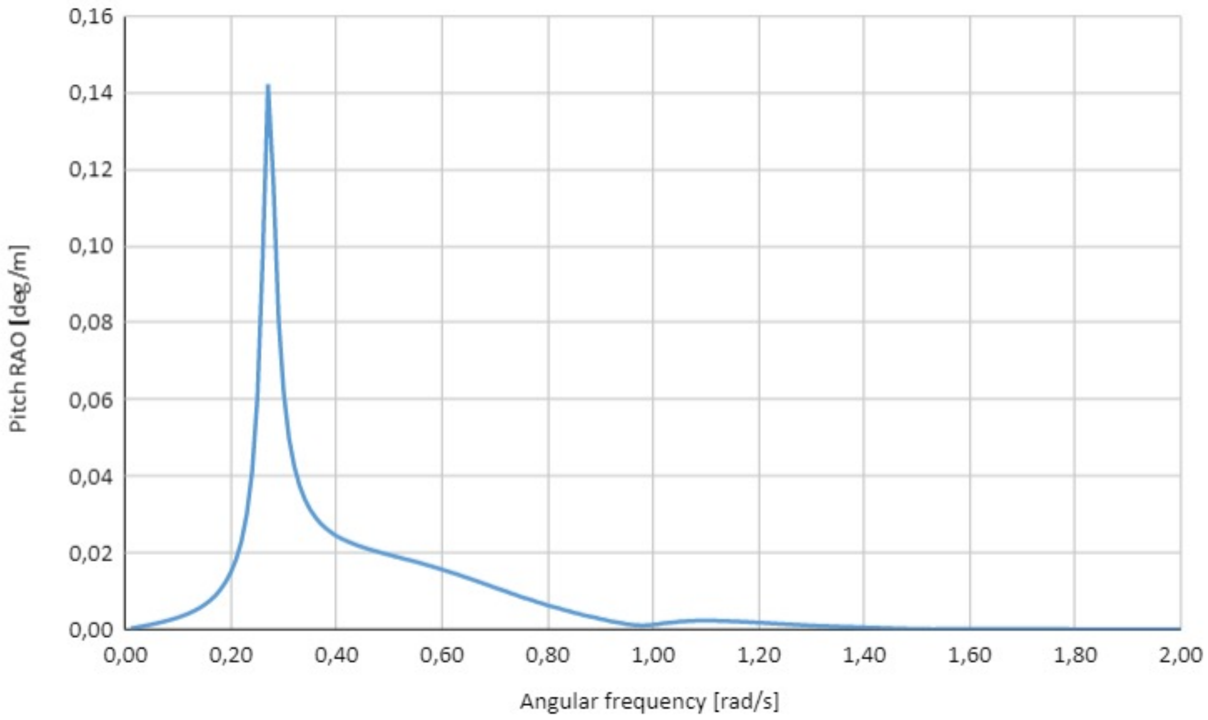
- Next, the natural period, damping coefficient and natural frequency were scaled to represent the values for the full-scale prototype using equations
- After calculating the spring constants C_{33} and C_{55}, added mass A_{33} and added inertia A_{55}, and the damping B_{33} and B_{55}, the RAOs are computed:

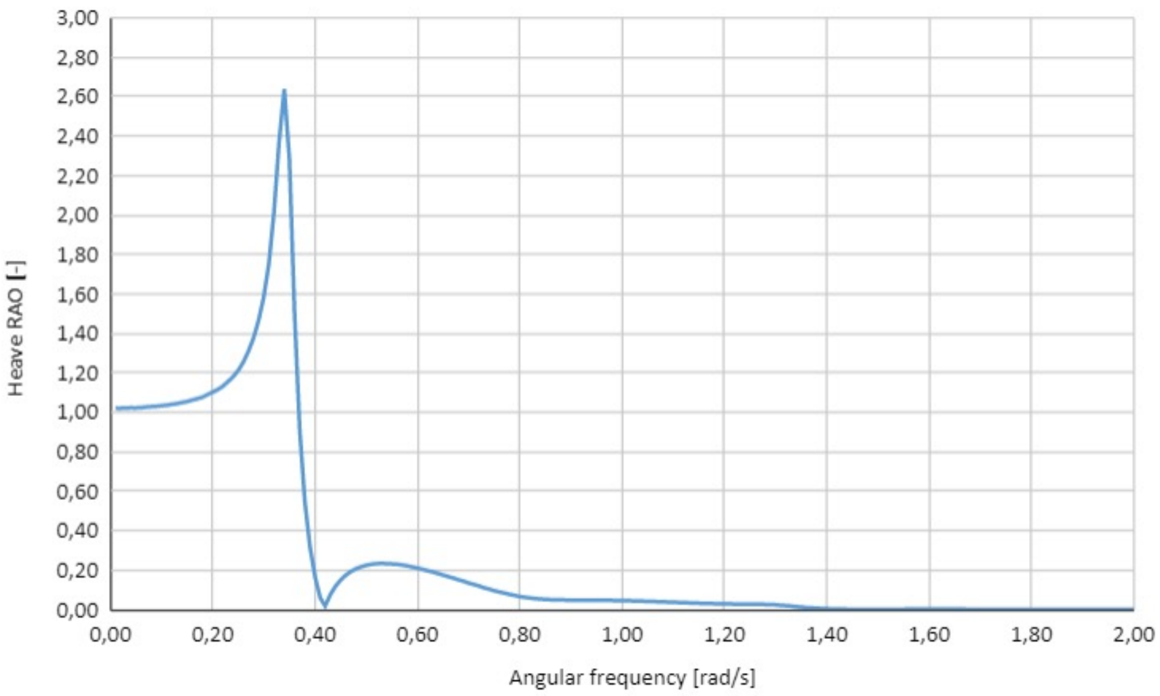
$$RAO_{33}(\omega) = \frac{X}{\zeta_a} = \frac{\frac{F_0(\omega)}{\zeta_a}}{\sqrt{\left(C_{33}-\left(M+A_{33}\right)\omega^2\right)^2+\left(B_{33}\cdot\omega\right)^2}} [-]$$

$$RAO_{55}(\omega) = \frac{\theta}{\zeta_a} = \frac{\frac{M_0(\omega)}{\zeta_a}}{\sqrt{\left(C_{55}-\left(J_{yy}+A_{55}\right)\omega^2\right)^2+\left(B_{55}\cdot\omega\right)^2}} \left[\frac{\circ}{m}\right]$$

RAO ESTIMATION FROM DECAY TEST

- The obtained graphs for heave and pitch are:





RAO ESTIMATION FROM MODEL TEST

- We now consider the semisubmersible platform model dynamics under regular wave excitation

- The Heave RAO is provided as non-dimensional value, the Pitch RAO must be scaled considering the following formula:

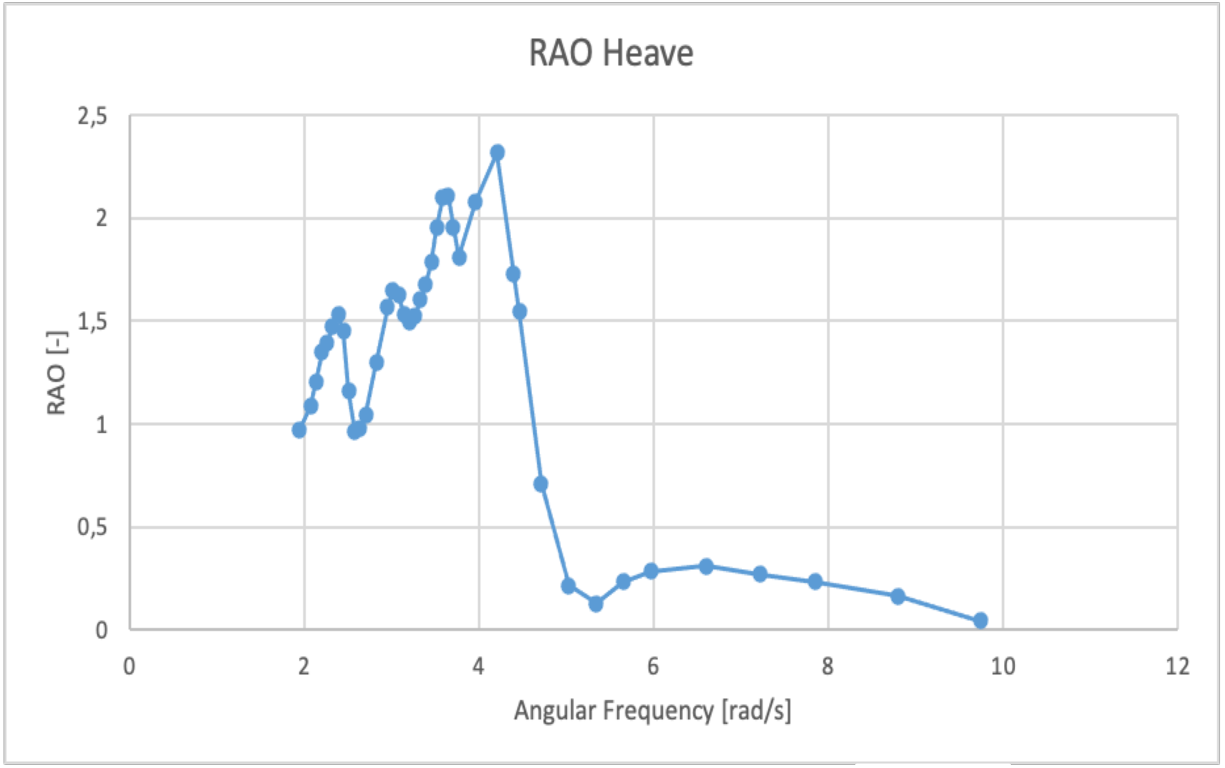
$$RAO_{pitch}\left[\frac{deg}{m}\right] * \frac{1}{\varepsilon} = RAO_{pitch}\,[-]$$

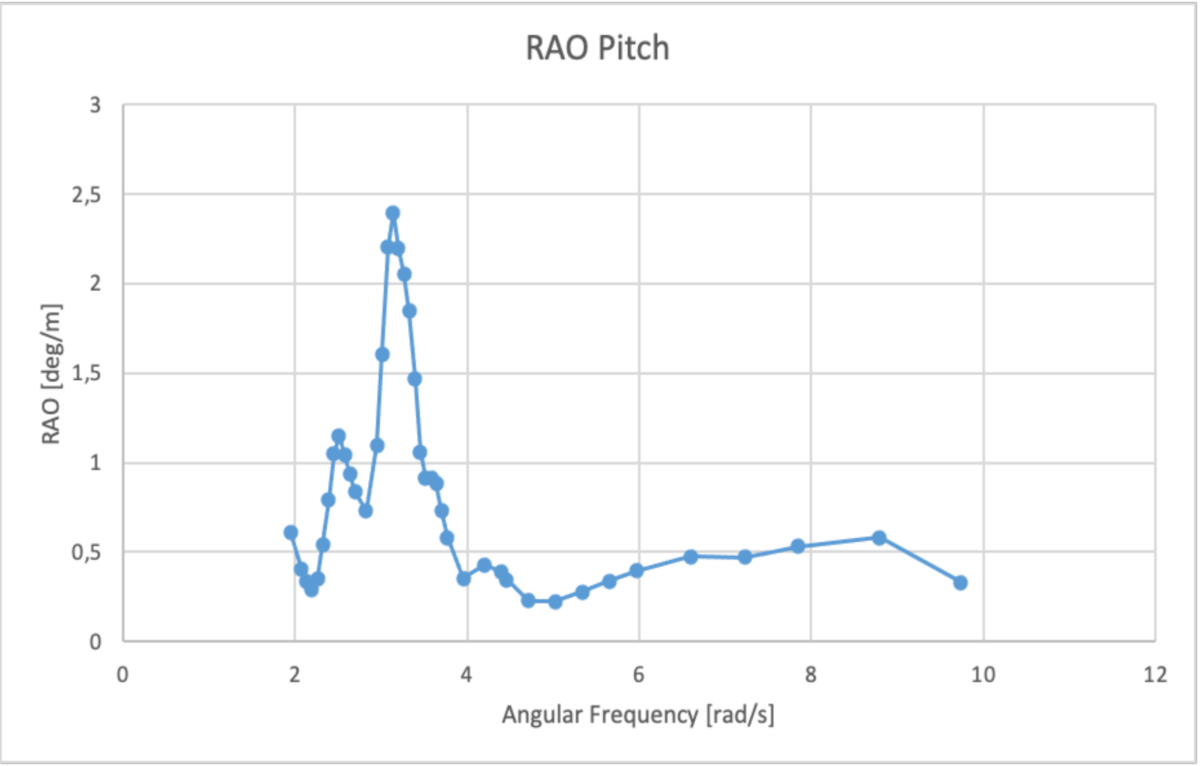
- It is also possible to compute these RAOs theoretically as:

$$RAO_{33}(\omega) = \frac{Z}{\zeta_{Have}}\,[m]$$

$$RAO_{55}(\omega) = \frac{Z}{\zeta_{Pave}}\,[m]$$

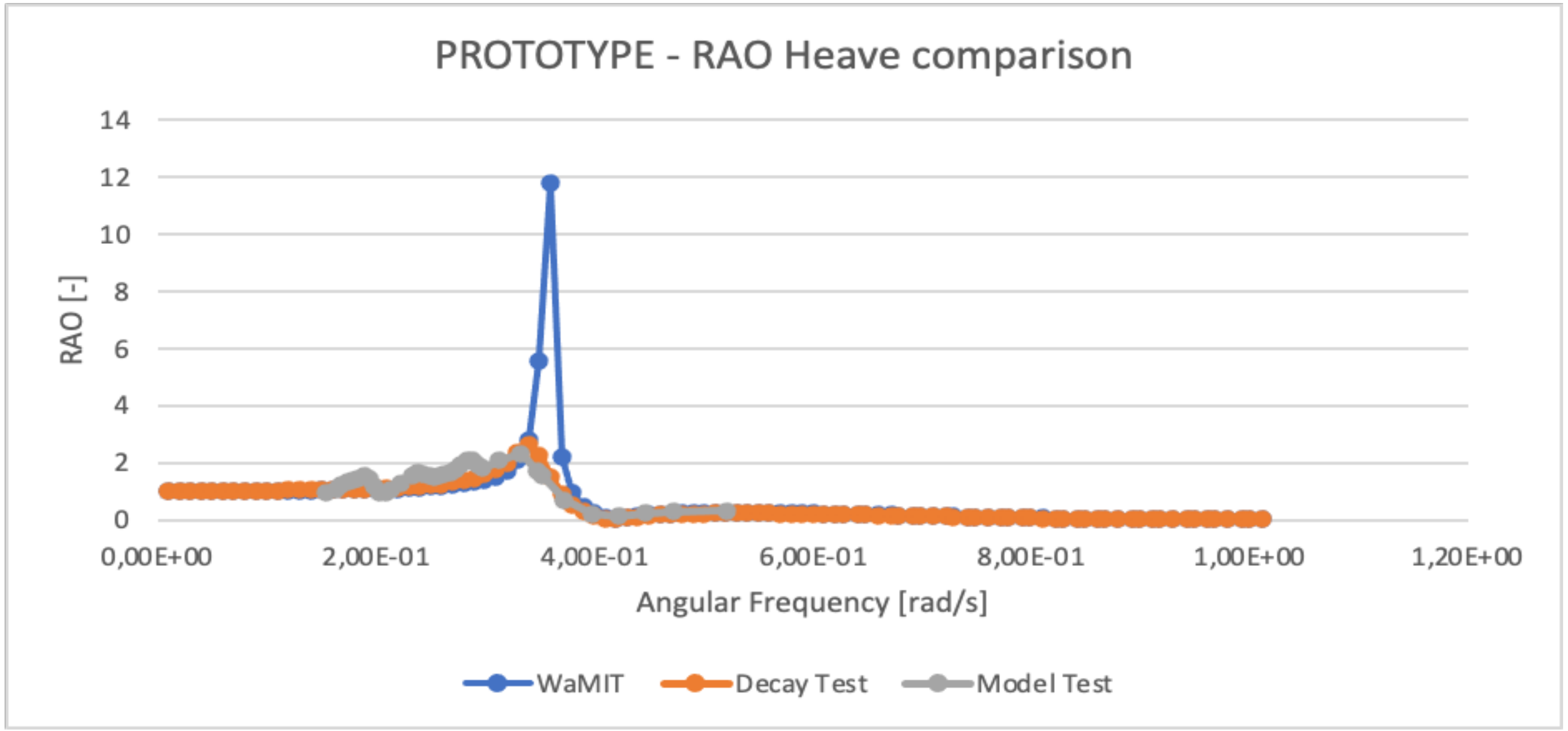
RAO ESTIMATION FROM MODEL TEST





CONCLUSIONS

- The results obtained thanks to the WaMIT analysis, decay test and model test are plotted together in the following graphs:



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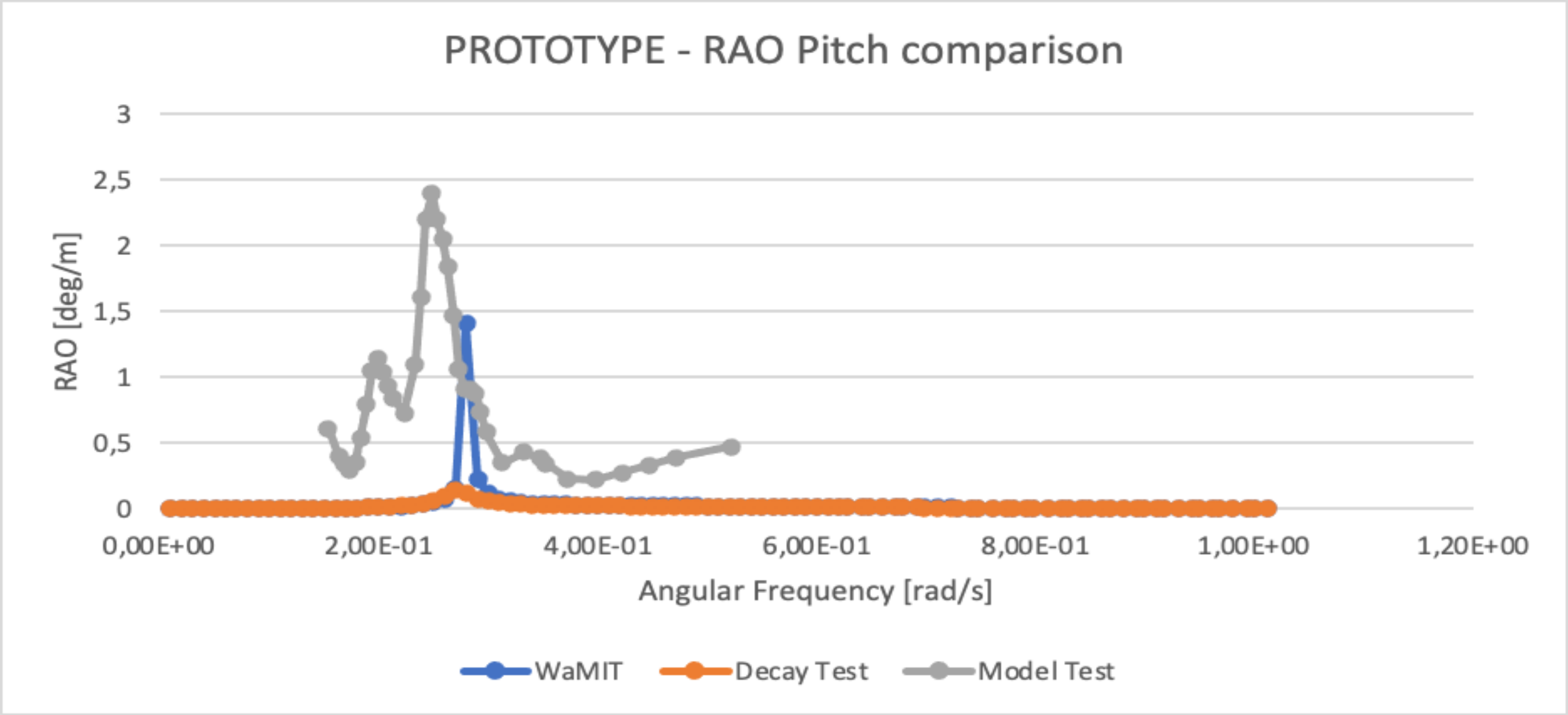

CONCLUSIONS

- The damping coefficient for heave and pitch is smaller in the **WaMIT analysis** because potential flow is assumed, as a consequence the RAO for this analysis is bigger than the others
- Regarding the **Decay Test**, the RAOs depend on the number of measurements taken in the lab, because the damping coefficient usually decreases with the number of measurements
- For the **Model Test**, the RAO for Pitch is much higher than the RAO computed with the other two methods, a explanation for this incongruity is that, since it is an experimental procedure, there will always be an experimental error in the measurements
- The most accurate method is the WaMIT analysis, it is also the most conservative
- The dimensional analysis is an important tool because we are able to study a small model in the lab and then the obtained results, properly scaled, can be applied to the full scale prototype