Hinged very large floating structures for wave energy conversion and wind turbine foundation

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Background

In this work, we explore the concept of a hinged very large floating structure (VLFS) to support multiple wind turbines and extract wave energy through hinge motion. Wave energy extraction can complement wind energy generation at times when the turbine needs to be shut down due to low or high winds. With such hybrid platform, a stable power supply could be achieved for applications that require constant power, such as electrolysers for offshore hydrogen generation. Furthermore, multiple wind turbines in a single floating platform can represent a cost reduction in offshore installations and a reduced environmental impact through a reduction in mooring lines.

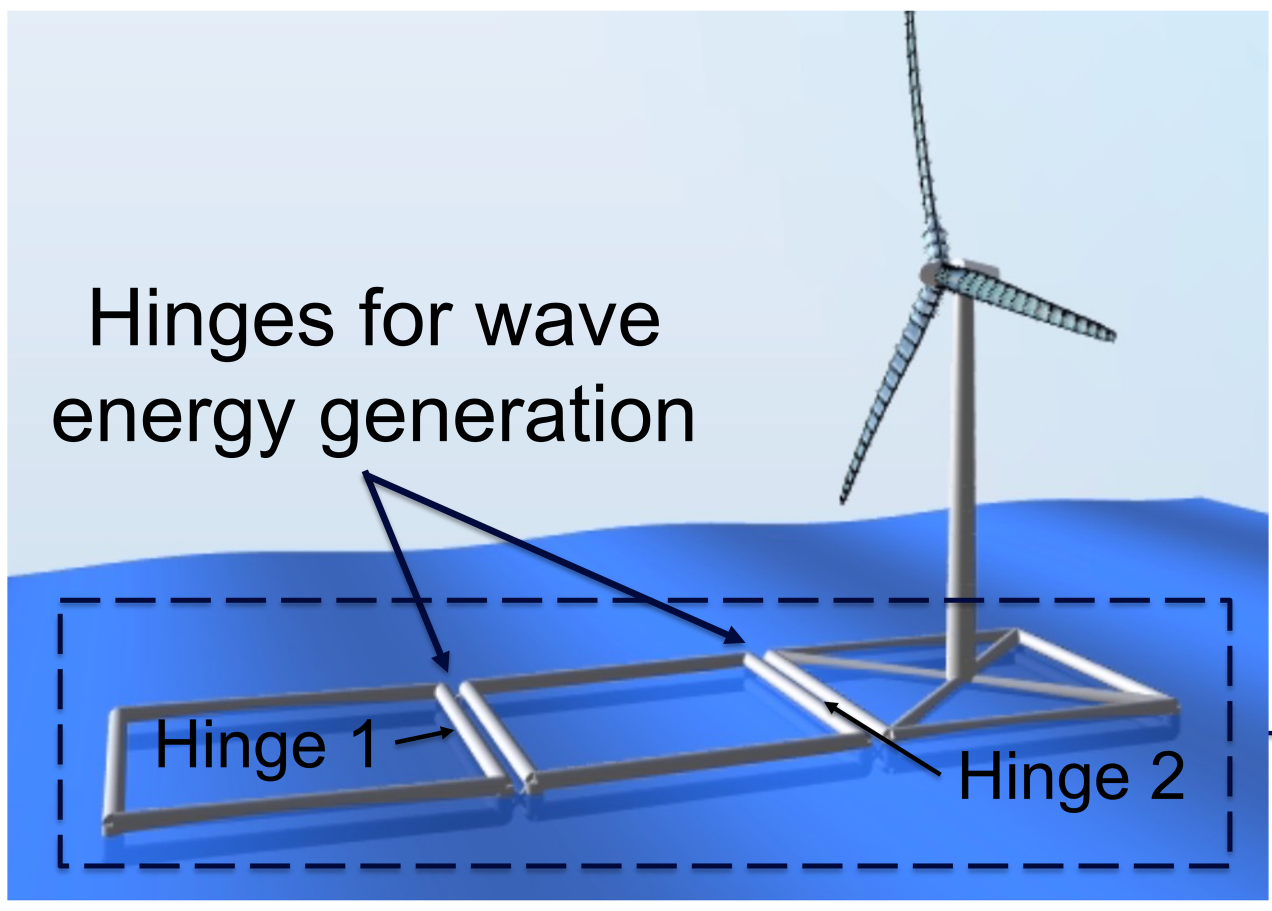

Figure 1– Hinged very large floating structure (VLFS) with 5MW NREL wind turbine

We study the case of a single turbine and a hinged VLFS (Figure 1). The pitch angle θ of the hinge can be computed through the hydrodynamic model, and therefore the angular velocity ($\dot{\theta}$) and acceleration ($\ddot{\theta}$). For systems that rotate and extract energy [2], the equation of motion is

$$\tau_{hydro} - \tau_{\mathrm{PTO}} = I\ddot{\theta},$$

where τ_{hydro} is the hydrodynamic torque on the hinge, τ_{PTO} is the power take-off torque and *I* is the moment of inertia (Figure 2). Then, the power captured by the hinge is

$$P = \tau_{pto}\dot{\theta}.$$

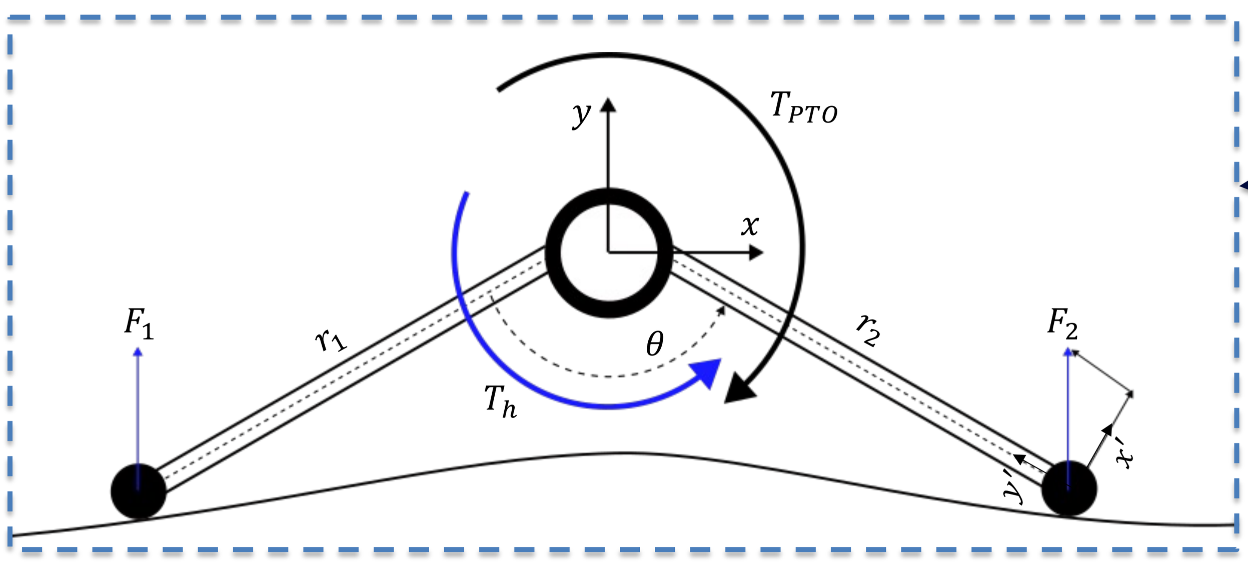

Figure 2– Hinge dynamic model details

Wind wave correlation

The complementarity of wind and wave energy extraction trough the hinged VLFS is explored first through the correlation of the wind and wave energy resources. Secondly, the correlation of the wind power and the wave energy extracted will be assessed. As an example, Figure 3 shows Metocean data from the ERA 5 data base from the ESOX tool for a location with low correlation of the coast of Spain, Villano Sisargas.

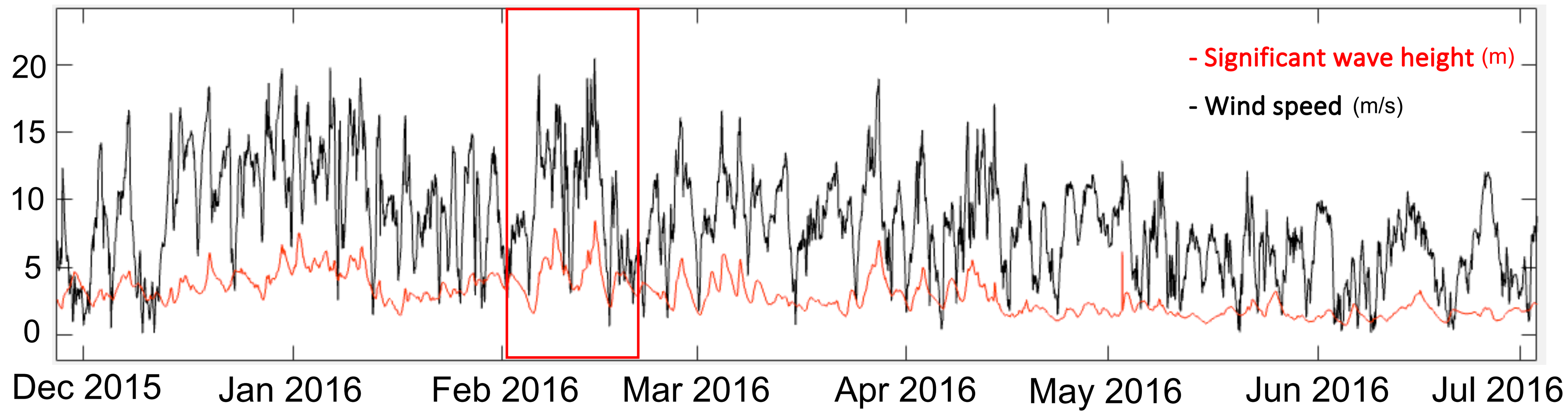

Figure 3– Wind and wave metocean data from Villano Sisargas, coast of Spain showing low correlation areas

Hydroelastic model of VLFS

The hydrodyelastic numerical model predicts the motion of the platform and the hinge through a discrete-beam-module approach (Figure 4). The model is described in detail in [1]. The turbine mass and thrust will be coupled initially in the frequency domain to the hydrodynamic model, and in a subsequent step in the time domain.

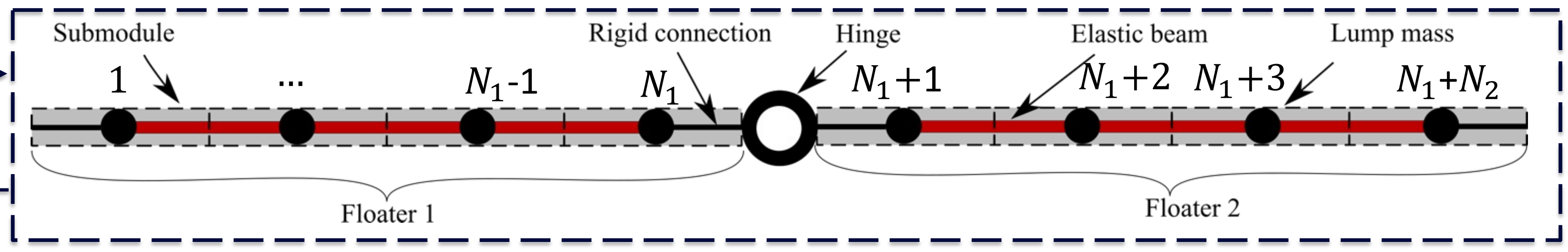

Figure 4– Hydroelastic model for the hinged VLFS (showing one hinge only)

Results

The amplitude of the heaving motion response (Δz) of the hinged VLFS (without turbine) is illustrated in Figure 5a for a regular wave of similar wavelength to the length of the VLFS ($\lambda/L \approx 1$). The numerical prediction (solid line) is compared to experimental data (markers) measured at different wave heights in the Kelvin Hydrodynamics Laboratory at the University of Strathclyde. Results are normalised with wave height. Figure 5a shows Δz along different stations of the VLFS along the normalised horizontal axis (*x/l*). Using the numerical and experimental results of Δz, Figure 4b shows the computed pitch angle for one of the hinges shown in Figure 1. Preliminary analysis of Figure 4b shows that there is a resonant frequency and that pitch angle grows with wave height.

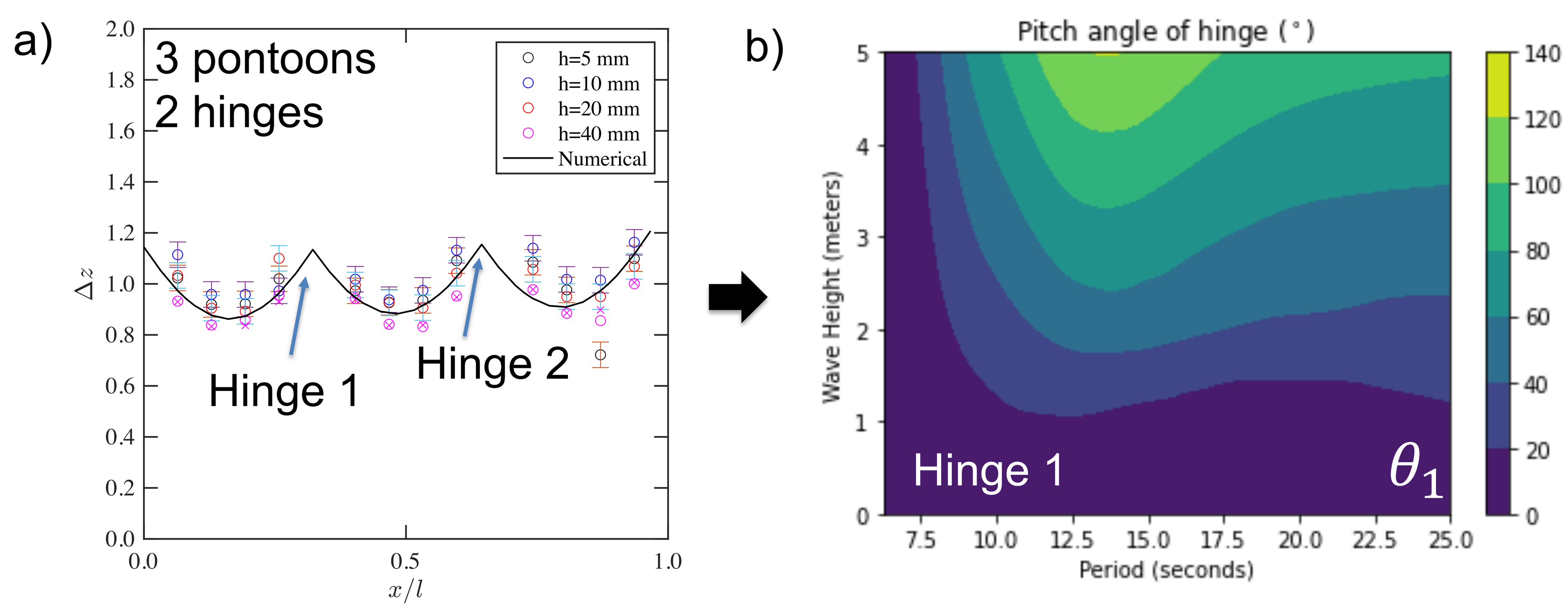

Figure 5– a) Heaving amplitude of hinged VLFS for $\lambda/L \approx 1$, and b) pitch angle for the first hinge as a function of period and wave height.

References

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2. Arredondo-Galeana, A., Ermakov, A., Shi, W., Ringwood, J. V., & Brennan, F. (2024). Optimal control of wave cycloidal rotors with passively morphing foils: an analytical and numerical study. Marine Structures, 95, Article 103597. Advance online publication. https://doi.org/10.1016/j.marstruc.2024.103597
3. Arredondo-Galeana, A., Chen, Y., Dai, S., Zhang, X., Brennan F. (2024). “Motion and load performance of rigid and hinged very large floating platforms” (Journal article *in preparation*).

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