A Numerical & Experimental Study of the Multi-Torus Floating Solar Island Concept

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Problem description

The multi-torus concept is proposed as the floating platform of a solar island. Solar islands is a futuristic, environmental-friendly method to furnish electricity as an example to coastal-near cities or to operate renewable liquid fuel factories extracting CO_2 from sea water. (Idea developed by Prof. Em. Bruce Patterson [1]).

The models are tested in regular and irregular waves for relevant sea conditions up to 7 m significant wave height. The hydro-elastic behaviour of the model is analysed, in order to document the appropriateness of the concept for desired sea conditions. The solar panel assembly is mounted on the floater for comparison. A numerical implementation of a simulation model is built in PYTHON. The numerical model combines a theoretical truss model by D. Marichal [2], modelling mooring lines and trusses connecting the tori, with a zero-frequency floater theory (ZFT) by O. M. Faltinsen [3].

Approach

$$l_k^2 = l_{0k}^2\left(1+\chi T_k\right)^2 \quad \text{where} \quad \chi = 1/EA$$

The truss model by Marichal is built on the equation above, which defines the length of truss k at time step $n+1$ as a function of the initial length l_{0k}, the stiffness factor χ and the tension T_k at time step n. The tensions $\bar{T}$ are unknown, and a system of equations $\mathbf{A}\bar{T} = \bar{b}$ is used to solve for the unknown at each time step n. The number of equations is decided from the number of trusses in the system. The length of a truss is defined as $l_k^2 = (x_j^{n+1} - x_i^{n+1}) \cdot (x_j^{n+1} - x_i^{n+1})$, where i, j are node ends. An Implicit-Explicit Euler time stepping method is used together with Newton's 2^{nd} law and the equation of motion to define all components of the system at time step n.

Figure definitions

1030_m1 Multi-torus with membrane exposed to wave series 1030 with steepness $H/\lambda = 1/30$.
1060_m1 Multi-torus with membrane exposed to wave series 1060 with steepness $H/\lambda = 1/60$.
1060 Multi-torus exposed to wave series 1060 with steepness $H/\lambda = 1/60$.
1030 Multi-torus exposed to wave series 1030 with steepness $H/\lambda = 1/30$.
ZFT Response amplitude operator for one torus using zero-frequency theory.

Acknowledgements

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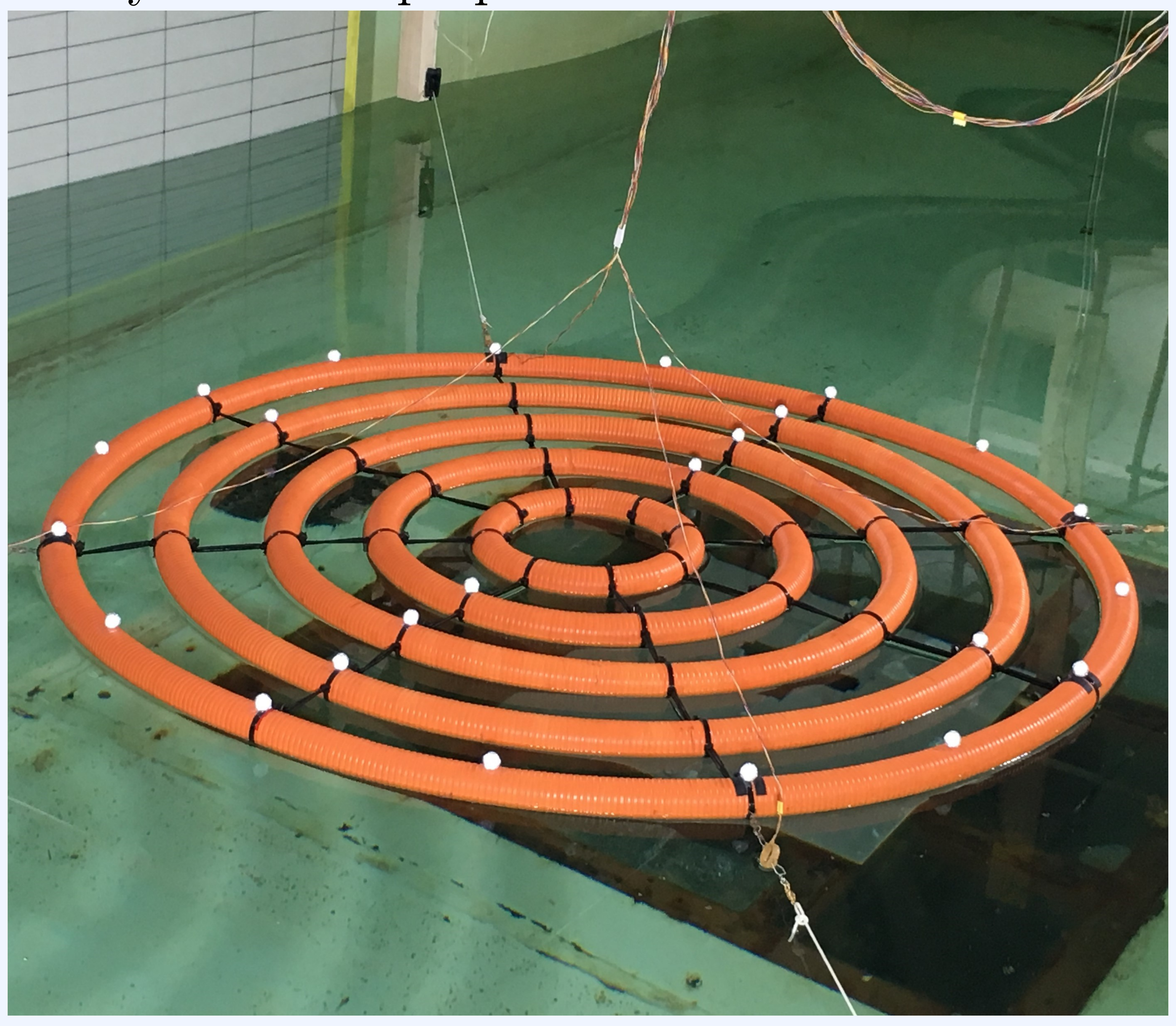
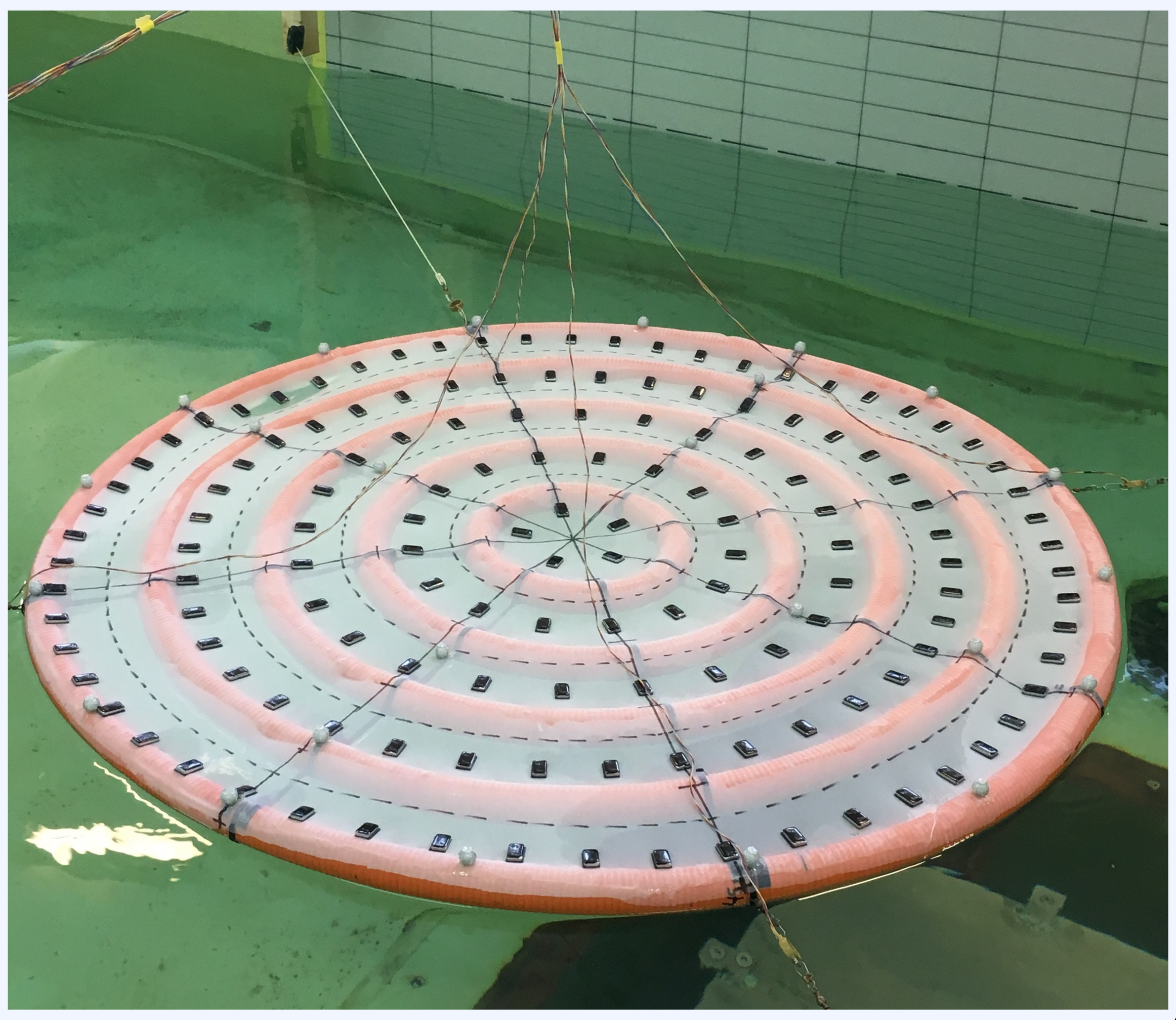
Multi-torus models

The multi-torus (left figure) is tested in the model basin *Lilletanken*, which is 25m long, 2.5m wide and has a water depth of 0.7m. It is built in scale 1:50, has a total diameter of 1.0m and consists of 5 circular tori, made of corrugated tube with water repellent tape wrapped around. Elastics and strips are used to connect the tori together at 8 symmetrical positions. A mooring line spring-system is connected to the model at 4 symmetrical positions. 24 OQUS sensors, seen as reflective globes on the model, are attached to the model measuring motion.

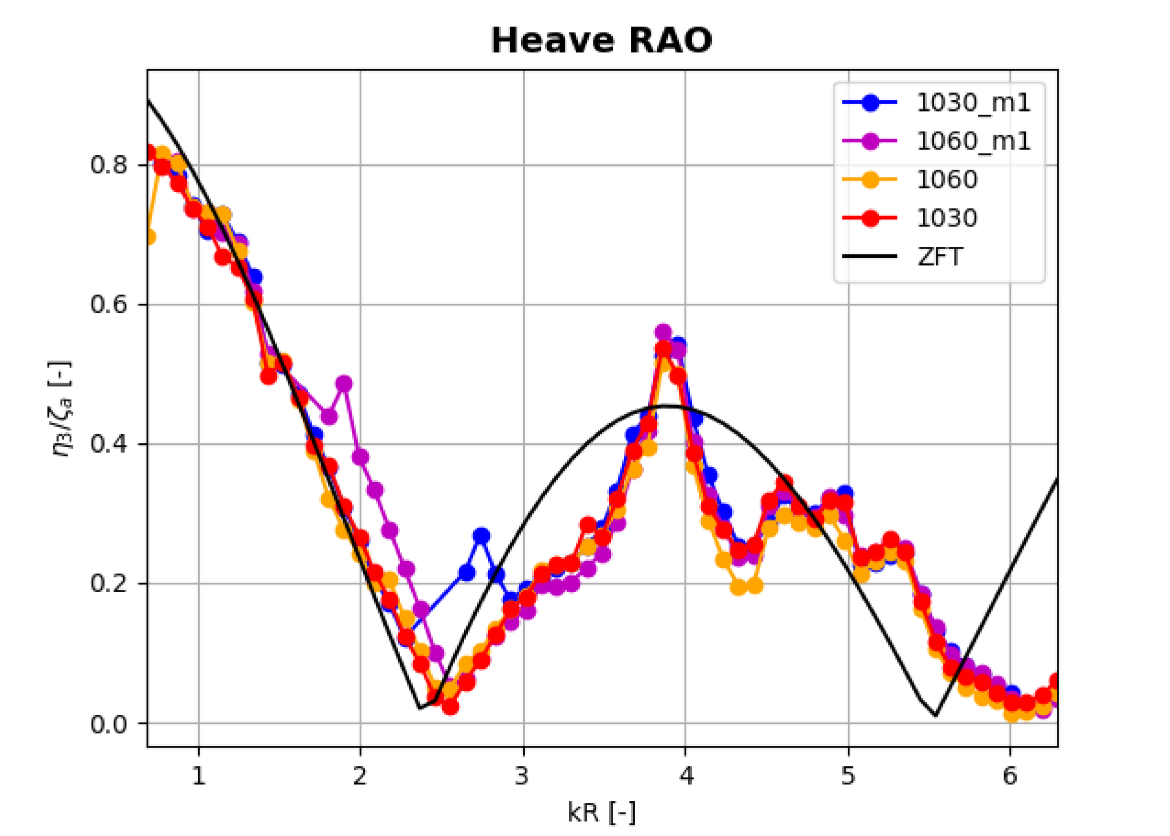
A model with weighted membrane (right figure) is also tested. The membrane is modelled to simulate the stiffness and weight of the solar panel assembly on top of the floater part. The goal is to compare the hydroelastic properties of the models with and without membrane.

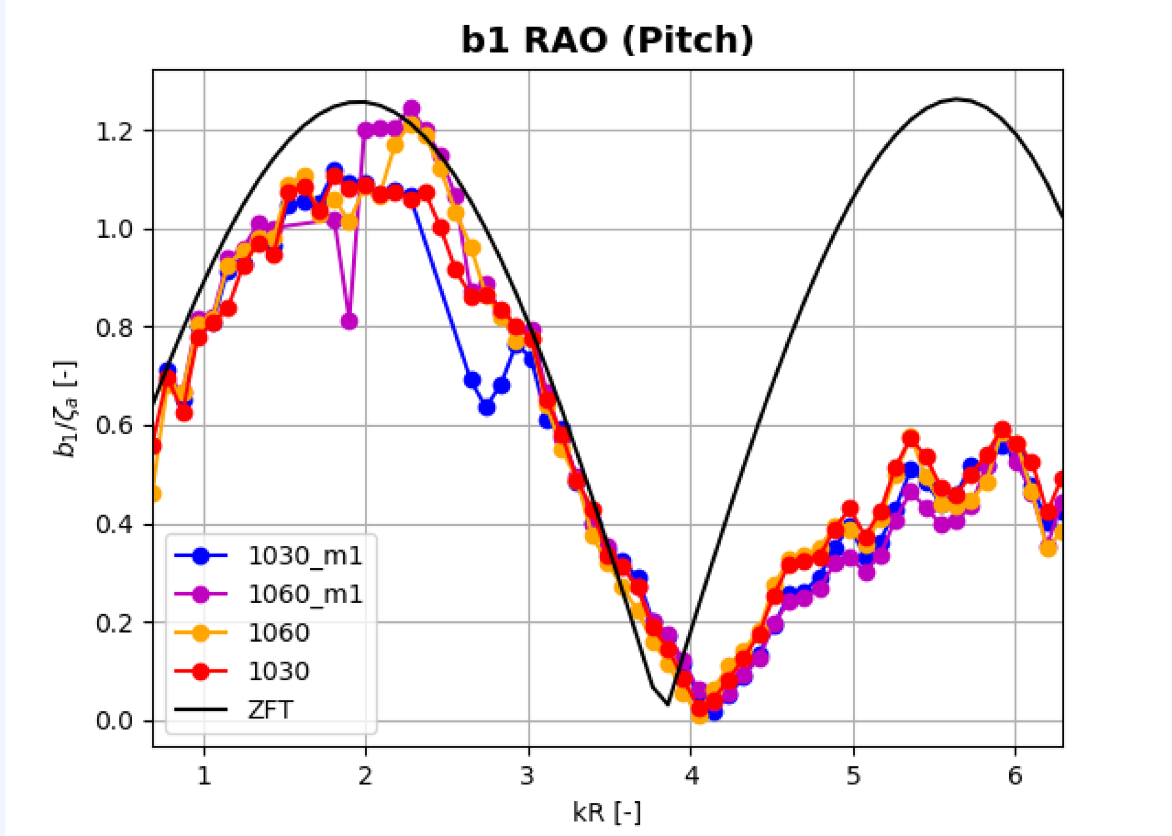


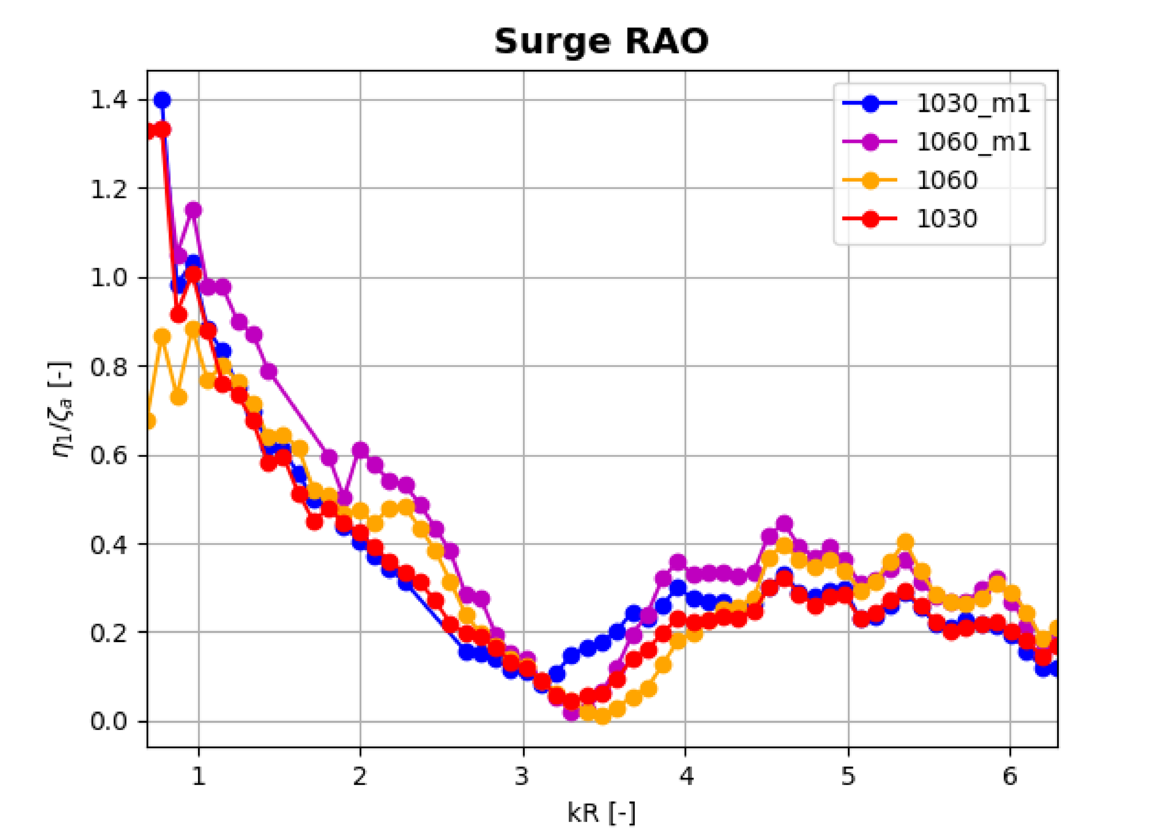


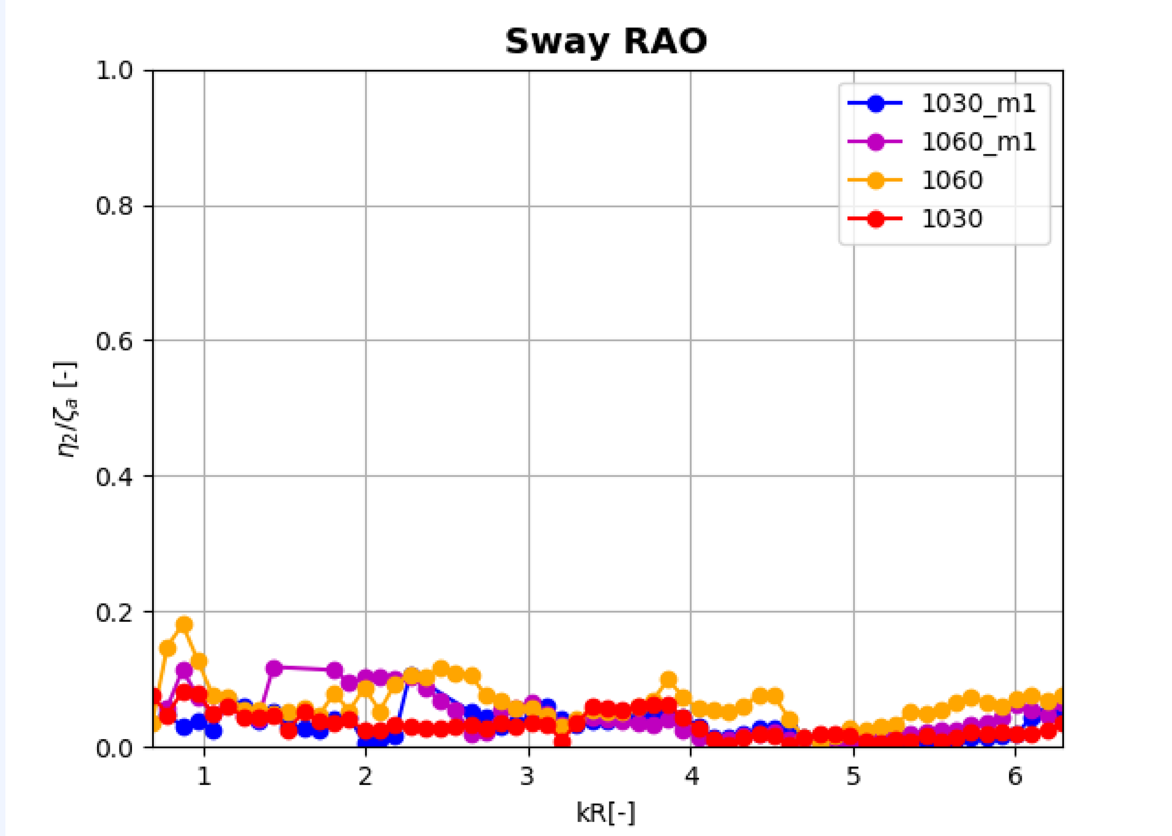
Wave-Induced Hydroelastic Response on Floater

The response amplitude operators (RAO) for heave, pitch, surge and sway for the outer torus are presented below, as function of the wave number k and the outer tori radius $R = 0.5m$. The RAOs are found from a modal analysis of the 16 OQUS sensors symmetrically positioned on the outer torus. The behaviour of the models with and without membrane are close to equal. The differences between model tests and ZFT are due to the effects of the other tori on outer torus, which are not included in the ZFT presented. Sway response is close to zero for all waves tested. Surge response reaches resonance close to $kR = 0.8$, as the surge natural frequency is approximated to 2.5s. The goal of the numerical simulation model is to better represent the behaviour of the outer torus, by implementing two tori, mooring lines and the trusses connecting the two.









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[3] O. M. Faltinsen *Hydrodynamic aspects of a floating fish farm with circular collar*, CeSOS & Department of Marine Technology, NTNU (2011)