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Dynamic Response and Structural Analysis of Aquaculture Structures

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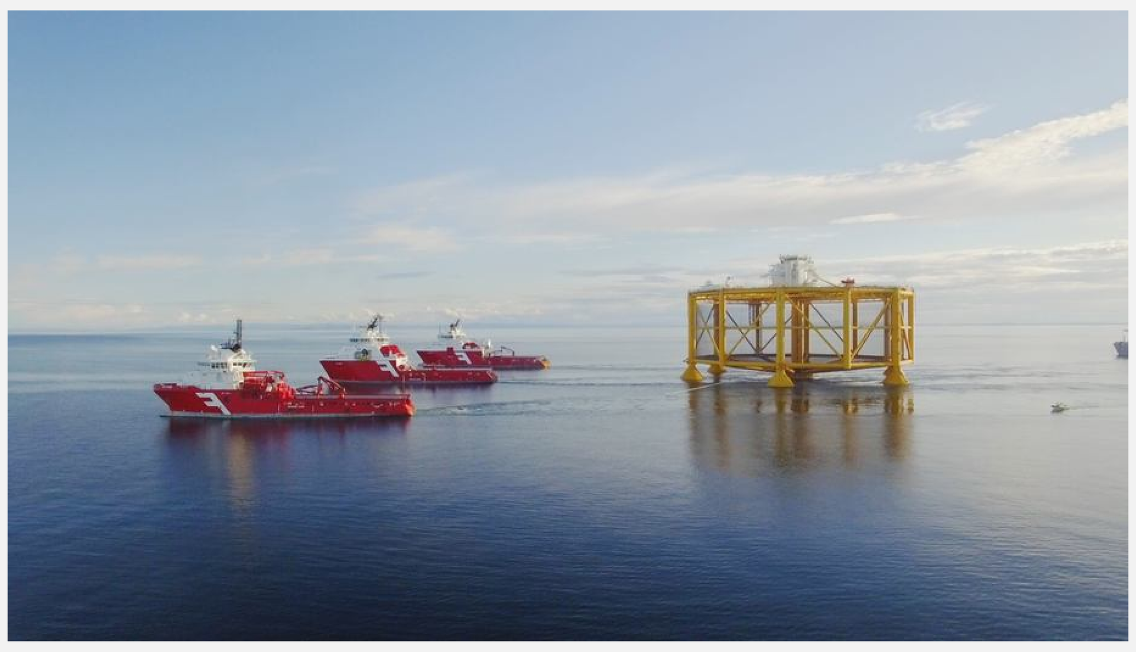
INTRODUCTION

The aquaculture industry is today one of the major food producing industries and is expected a further growth in order to contribute in feeding the ever growing population. The Norwegian coastline has proven to have excellent conditions for fish farming, making the aquaculture industry one of the major industries along the coastal areas of Norway. However, driven by acreage and environmental challenges, the Norwegian Directorate of Fisheries no longer recognize further expansion of the industry as sustainable. Therefore, they now encourage companies to look towards the open sea as future production sites.

As of 2017, Ocean Farm 1 became the first offshore fish farm in Norwegian waters, and is now working as a full-scale pilot facility [1].



OBJECTIVE

The objective of the thesis is to illustrate the modelling and analysis process undergone in design of floating structures by performing a global response analysis on an offshore fish farm model. The fish farm is modelled as a coupled SIMO-RIFLEX model in SIMA. The results obtained from analyses in SIMA will be compared to results obtained from model tests performed by MARINTEK. The analyses to be performed includes

- Convergence study
- Static analysis including self-weight and buoyancy
- Static analysis including current loads
- Dynamic analysis in regular waves
- Eigenvalue analysis

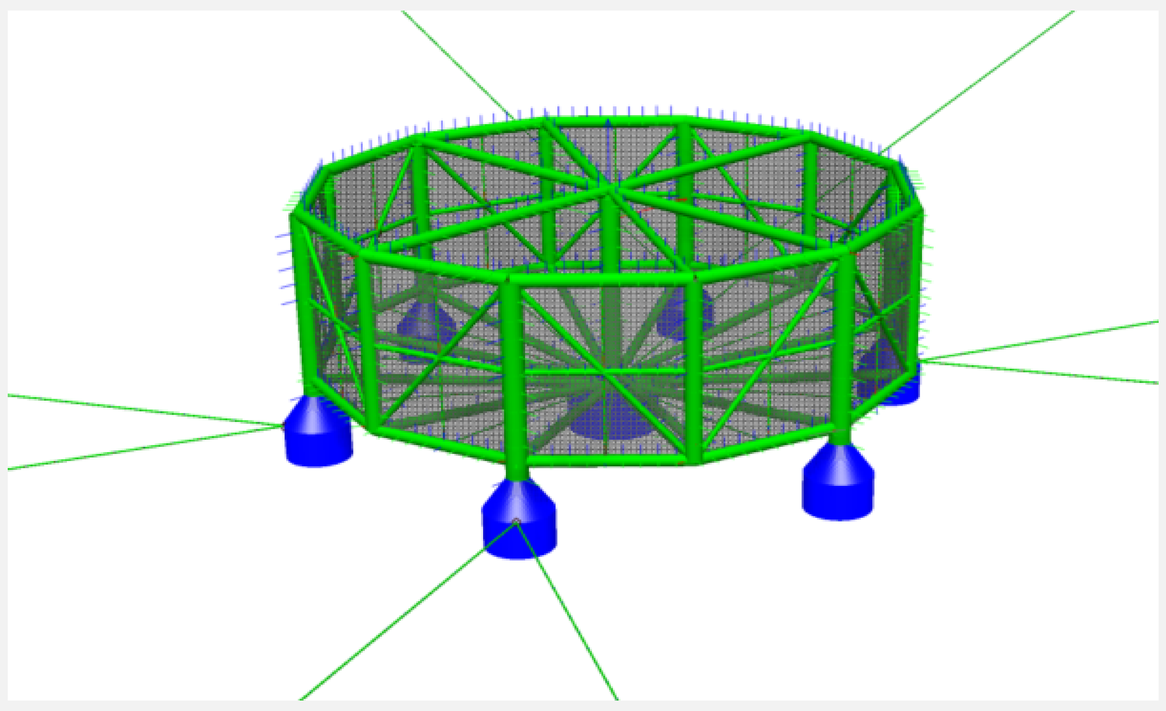
REFERENCES

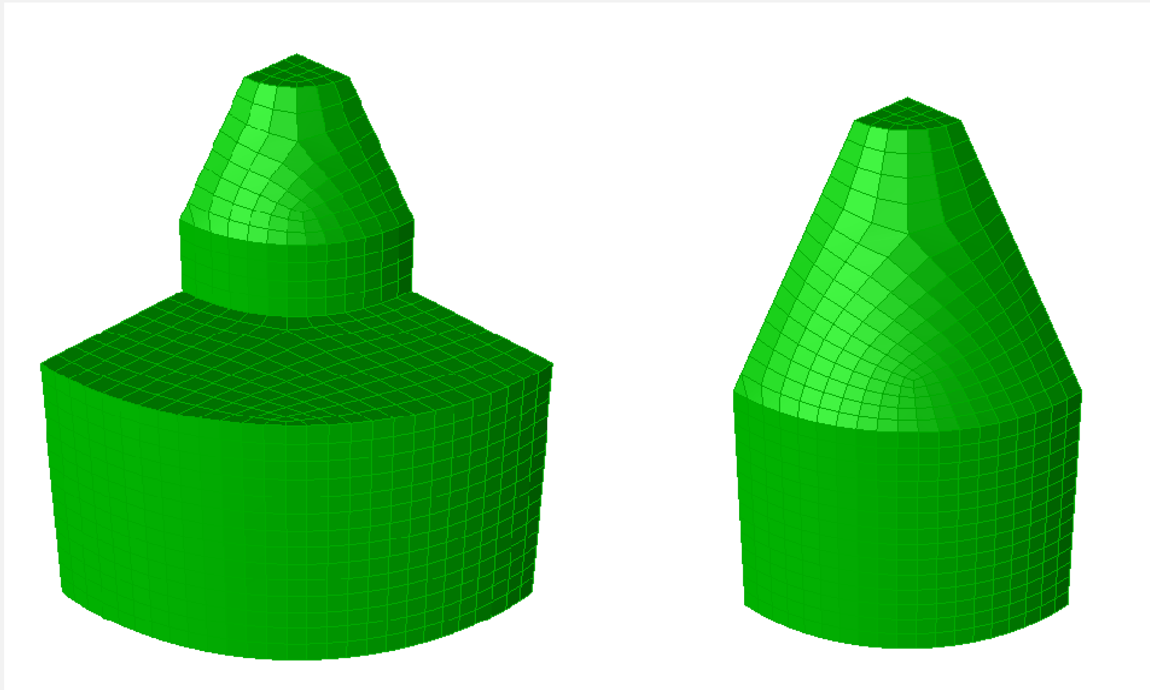
[1] SalMar [Internet]. *Offshore Fish Farming.* Accessed from: `https://www.salmar.no/en/offshore-fish-farming-a-new-era/`

[2] SalMar Gallery. *Ocean Farm 1 Towing*, [Image on the internet]. Accessed from: `https://www.salmar.no/en/gallery/`

MODELLING

All parts of the fish farm model with exception of the pontoons are modelled as slender elements in RIFLEX. This includes the hull structure, mooring lines and fish net and can be seen as the green parts of the left figure. The pontoons are made as panel models in GeniE. The meshed panel models are shown in the right figure below. Only one quarter is modelled as one can utilize the double symmetry of the bodies, saving computational time and storage capacity. The panel models are then exported to HydroD where the Wadam module is used to perform a hydrodynamic analysis in the frequency domain. A mesh convergence analysis of the hydrodynamic results are performed in order to determine a proper mesh size for the GeniE panel models.





The results from the hydrodynamic analysis in HydroD and body geometry from GeniE are then imported to SIMA, where SIMO bodies of the pontoons are created. These are seen as the blue parts of the left figure above. The SIMO body properties include information as structural mass data, linear damping matrix, hydrostatic stiffness data, first order wave force transfer functions, retardation functions and added mass at infinite frequency. After attaching the SIMO bodies to the RIFLEX structure, gravity, buoyancy and ballast must be added.

RESULTS

The convergence analysis of the hydrodynamic results in HydroD resulted in a mesh size of 0.5 x 0.5 meters for the pontoon panel models. Convergence of the first order wave force transfer function in heave for a wave propagation angle of 45° is shown in the upper figure.

The static analysis including current loads gave a surge offset of 19.6 meters from the initial position. A pitch angle of 0.13 degrees and a reduced airgap of 40 cm is also observed. Static forces and bending moments were generally small, suggesting that fatigue might be the most important failure mode for the structural members of the hull.

The middle figure shows the maximum recorded mooring line tensions during the regular wave analysis with the 100-year environment for three different wave directions. A comparison of results from regular waves with different wave heights are also tested in order to determine the effect of increasing wave heights. The results shows that the mooring system gives higher restoring forces for the in-between direction than for the in-line direction, and that the safety factor with reference to MBL is high even for extreme weather conditions.

The bottom figure shows the nodal displacements for the top node of the center column for regular waves with increasing wave heights. The displacements follows similar patterns for all wave heights, indicating a linearity in the dynamic response. It is also observed quite large surge displacements compared to the MARINTEK model tests, indicating a lack of stiffness in the mooring system modelled in the thesis.