Ultimate- and Fatigue Limit State Analyses on a Rigid Offshore Aquaculture Structure

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Introduction

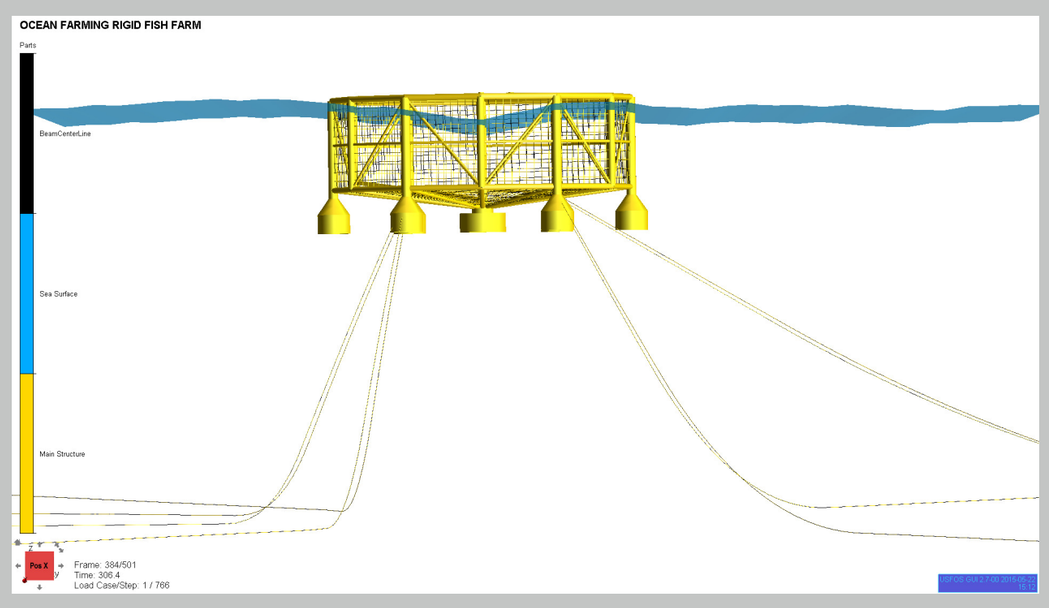
- Marine fish farming is in rapid development. Dimensions are expected to increase, and locations are being moved to areas exposed to more energetic waves and stronger currents. Collapse of fish farms, with large scale fish escape to the level experienced in the past, will not be tolerated by the society. New and extreme loading scenarios need to be properly designed for by means of "first principles" methods to meet the required safety levels and performance.
- Rational design requirements for aquaculture structures must be developed based on simulations of the governing physical phenomena, structural load effects, and structural resistance.
- Simulations on one of the concepts designed to counter many of the challenges facing the industry today, among others, large scale escapes and the growing problem of salmon lice, have been run during this master thesis. The concept is developed by Ocean Farming, a R&D subsidiary of SalMar ASA.
- The project is still in the planning phase and thus confidential. The results and methods presented and described here are therefore severely limited. The following are material we consider to be common knowledge seeing as this concept have been mentioned in the media on several occasions.

Objectives

1. Model Ocean Farming's rigid offshore fish farm in USFOS as correctly and updated as possible according to structural drawings.
2. Conduct ultimate state limit (ULS) analyses by adopting existing rules and regulations from the offshore industry and code-check accordingly.
3. Conduct fatigue limit state (FLS) analyses based on omnidirectional statistical wave-data measured at the intended location.
4. Make a qualitatively comparison with results from MARINTEK, Global Maritime, and earlier students.

Modelling

- A significant amount of time has been invested in modelling the structure as correctly as possible. By correctly, we mean getting the right structural weight, member dimensions, centers of gravity and buoyancy and filling ratio in the pontoons. In addition, catenary profiles on the mooring lines, directionally dependent drag coefficients on the scaled net structure, material properties of the different components, etc. should be considered.
- The model has been checked by a qualitative comparison of natural periods with earlier work (on an earlier design).



Conclusion

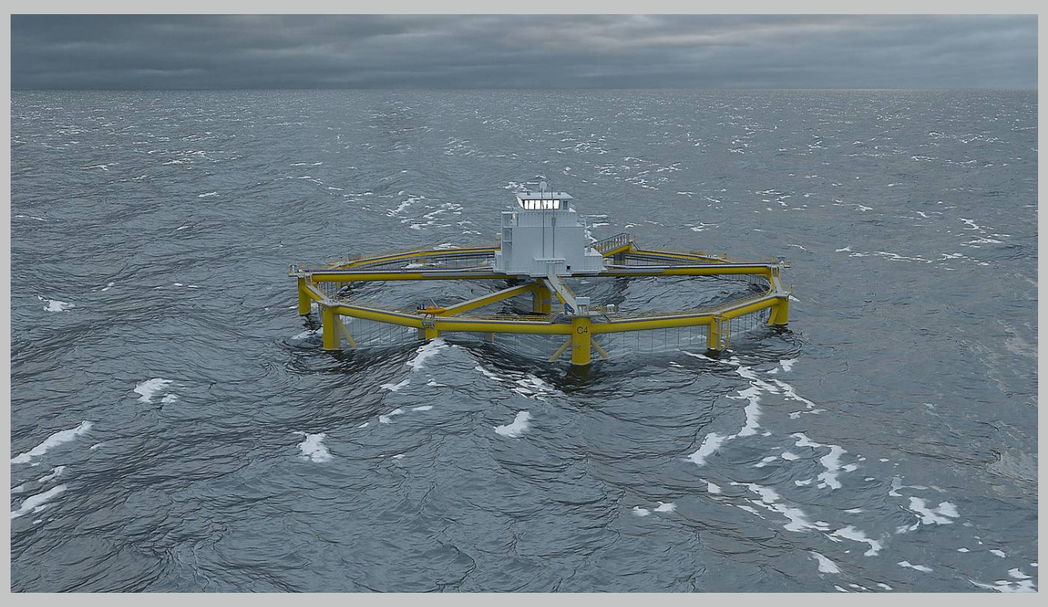
- Our simulations yielded satisfactory results compared to earlier work and have hopefully provided the concessionaires with valuable information.
- Much work remains however, and as a suggestion to further work we would recommend running more detailed limit state analyses on the whole range of sea-states and directions.

Analyses

- Analyses have been performed in USFOS (non-linear finite element software) and a selection of accompanying software modules for post-processing.
- Sea-state and directional statistics have been made and applied to the simulations according to on-site measurements.
- **Ultimate limit state** (ULS)
  1. Simulations have been run with waves and current coming from 7 directions inside a "quadrant" of the model.
  2. For each direction, 400 second simulations of 40 seeds on 1.-3. highest wave (totalling 120 simulations) were performed. The wave that gave the highest utilization (API-WSD) is kept as a result.
- **Fatigue limit state** (FLS)
  1. Simulations have been run with waves coming from 8 directions around the rig.
  2. For each direction, 15 different sea-state simulations of 1 hour, totalling 120 simulations combined.
  3. Results are summarized to lifetime and presented as a parametric study of stress concentration factors for the most critical members.

Illustrations

- Two illustrations made by SalMar/Ocean Farming. In the upper figure, the rig can be seen in relatively calm waters accompanied by a wellboat. In the bottom figure, the rig can be seen in operative state in harsher weather.



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