

## Rational analysis of Nordlaks' "Havfarm" aquastructure concept for exposed waters

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### Contribution/Introduction

A Hydrodynamic and a Finite Element model of the Havfarm structure is established based on information provided by NSK Ship Design. With Use of Bureau Veritas software a direct hydro-structure analysis of the Havfarm is conducted. This involves a hydrodynamic analysis of the structure to establish critical wave frequencies and headings, establishment of a long term distribution of selected response quantities, establishment of three Equivalent Design Waves (EDW) and finally a Finite Element Analysis (FEA) for the EDW cases is performed to determine characteristic stress values in the structure. Hydrodynamic effect of the lice skirts is neglected, the nets holding the fish are completely neglected.

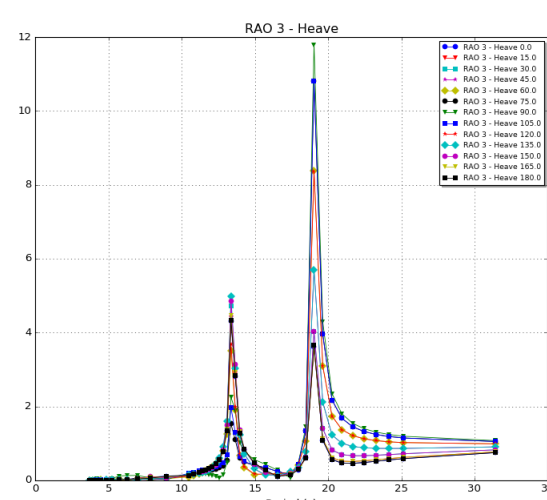


Figure 1: RAO Heave

### Theory

The hydrodynamic analysis is based on potential theory and performed in the frequency domain. Frequency domain analysis benefits of fast and efficient computation, however the results will only account for 1. order effects and thus only valid for low and medium sea states. Further the analysis model is based on potential theory. Hydrostar, the seakeeping software used, is based on the Boundary Integral Equation (BIE) method based on the source formulation is used to solve the Boundary Value Problem (BVP) for different potentials. Within the source formulation, the potential at any point in the fluid. This is an important advantage as this makes Homer capable of accurately transfer the pressure from the hydrodynamic model to the structural model, ensuring implicit balance between the models. [1]

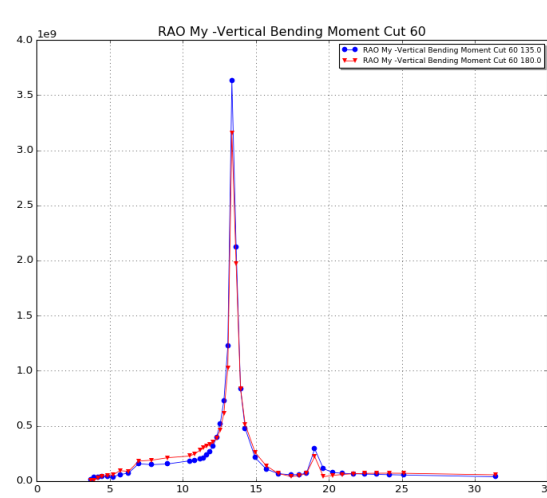


Figure 2: RAO Vertical Bending Moment

Based on metocean data provided by NSK Ship Design an estimate of Ultimate Limit State(ULS) internal loads are established.

### References

[1] Faltinsen, Sea Loads on Ships and Offshore Structures [2] Hydrostar user manual

### Analysis and Results

Table 1: Hydrodynamic properties of the Havfarm Structure

M	0.373E+08 kg
$A_{33}(17.9s)$	0.364E+08 kg
$A_{waterplane}$	0.909E+03 $m^2$
Displaced Volume	0.361E+05 $m^3$

Firstly Response Amplitude Operators (RAOs) are established for motions and internal loading, such as vertical, horizontal and torsional bending moment. The RAO for heave motion is shown in figure 1 and for the vertical bending moment in figure 2. Based on the hydrodynamic properties given in table 1 equation 1 [2] gives a natural period in heave of 17.9S which is roughly the same as the period of 19s appearing in figure 1. The difference is because equation 1 is for uncoupled natural period were as Hydrostar accounts for coupling effects. The other peak occurring around 13.2s is caused by the natural period in pitch. An extreme value of the vertical bending moment corresponding to a 100 year value is estimated based on the RAO for the vertical bending moment given in figure 2, as well as for the horizontal and torsional moment.

$$T_{n3} = 2\pi \left( \frac{M + A_{33}}{\rho g A_{wp}} \right)^{1/2} \quad (1)$$

Table 2: EDW

Targeting Value	VBM	HBM	TM
ULS-value [MNm]	14300	3750	916
RAO [MNm]	3630	652	148
T[s]	13.4	6.28	6.28
H[m]	3.9	5.8	6.2
Wave Dir[Deg]	135	105	105

Three EDW is established with properties and targeted quantity and value as shown in table 2. Note that the Horizontal and Torsional bending moment is targeted with the same EDW. This EDW can be seen in figure 3. The Havfarm is wived form above for the worst possible load case. The red indicates wave crest and the blue the trough.

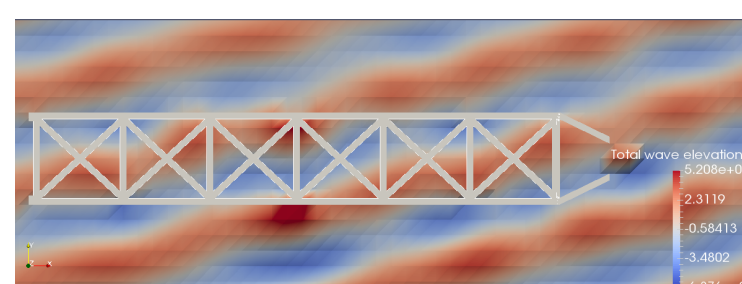


Figure 3: Havfarm structure seen from above subjected to the Horizontal EDW. The wave are propagating in the "north west" direction

The deformation caused by the EDW targeting maximum horizontal bending moment and torsional moment is shown in figure 4. The deformations are scaled to give a clear view of the effects. It can clearly be seen that the structure is subjected to torsion as the bottom pontoons deflects more than the top ones due to the lack of stiffening structure.

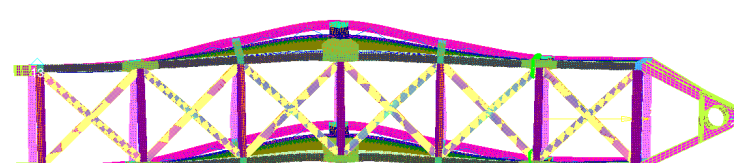


Figure 4: Deformations due to the Horizontal EDW

Hotspot stresses of the Horizontal/Torsional EDW can be seen in figure 5. These occur in the connections with the top pontoons where we have sharp corners.

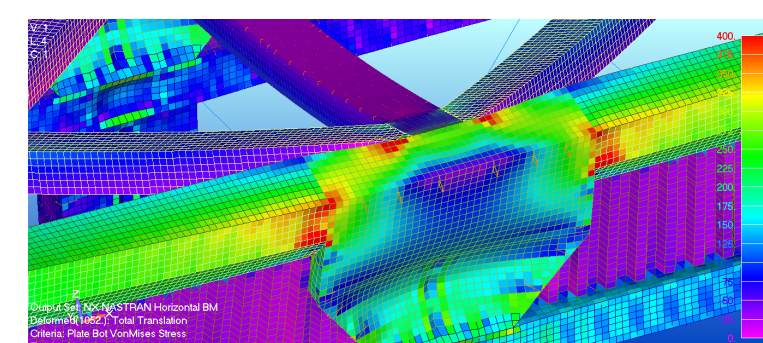


Figure 5: Hot spots due to the horizontal EDW

Figure 6 shows the FEA results from the EDW targeting the vertical bending moment. It can clearly be seen that the top and bottom pontoon are overstressed with stresses exceeding 400 [MPa]. Figure 7 shows the hot spots in the same area as 6 but with a different stress scale. Here the red spots indicate a stress of 600 [MPa]. Again the hot spots are mainly found in the connections with the pontoons and columns.

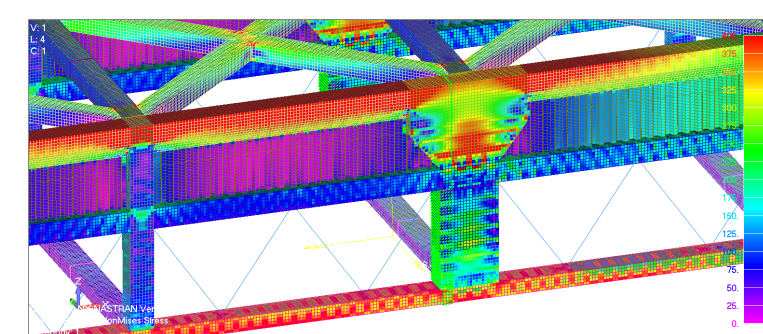


Figure 6: Over stresses in the pontoon due to the EDW targeting maximum vertical bending moment

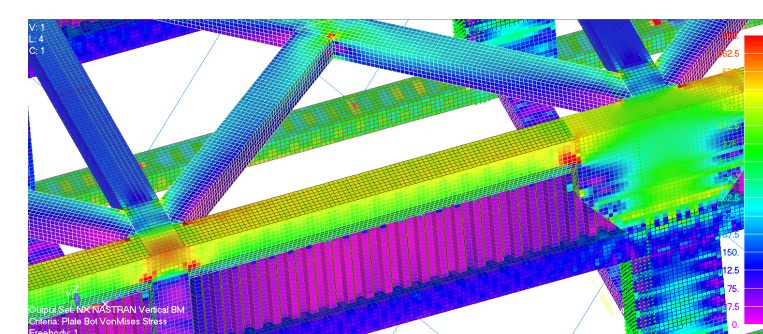


Figure 7: Hotspots due to the EDW targeting maximum vertical bending moment

**Proposals** To ensure sufficient strength and avoid overstresses due to the ULS loading it is proposed to increase the plating thickness of the top and bottom pontoons. The hot spots should be further investigated with a refined mesh. As the model is quite detailed already this will probably give the same results. To resolve the hot spot issues it is proposed to strengthen sharp connections with large brackets and larger radius in the connections to avoid large stress concentrations.

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