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6th EMship cycle: October 2015 – February 2017

Master Thesis

Fatigue Analysis of Semi-submersible

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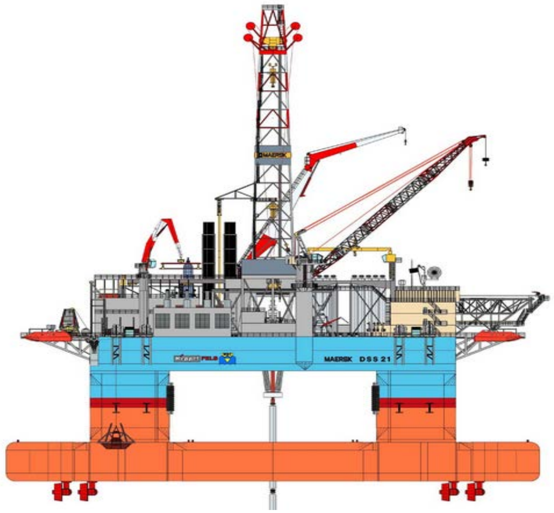
Szczecin , February 2017

Contents:

A semi-submersible is usually with minimum 20 years design life and it is exposed to environmental loadings and payload due to different operating conditions.

The cyclic loads bring possible fatigue problems and every welded joint and structural detail or other form of stress concentration is a potential source of fatigue cracking and should be taken into consideration as well.

Fatigue assessment which is supported by a detailed fatigue analyses are performed to make sure that the structure exposed to extensive dynamic loading has an adequate fatigue life.



Objective:

Preliminary fatigue analysis on a semi-submersible hull. (Ring-pontoon)

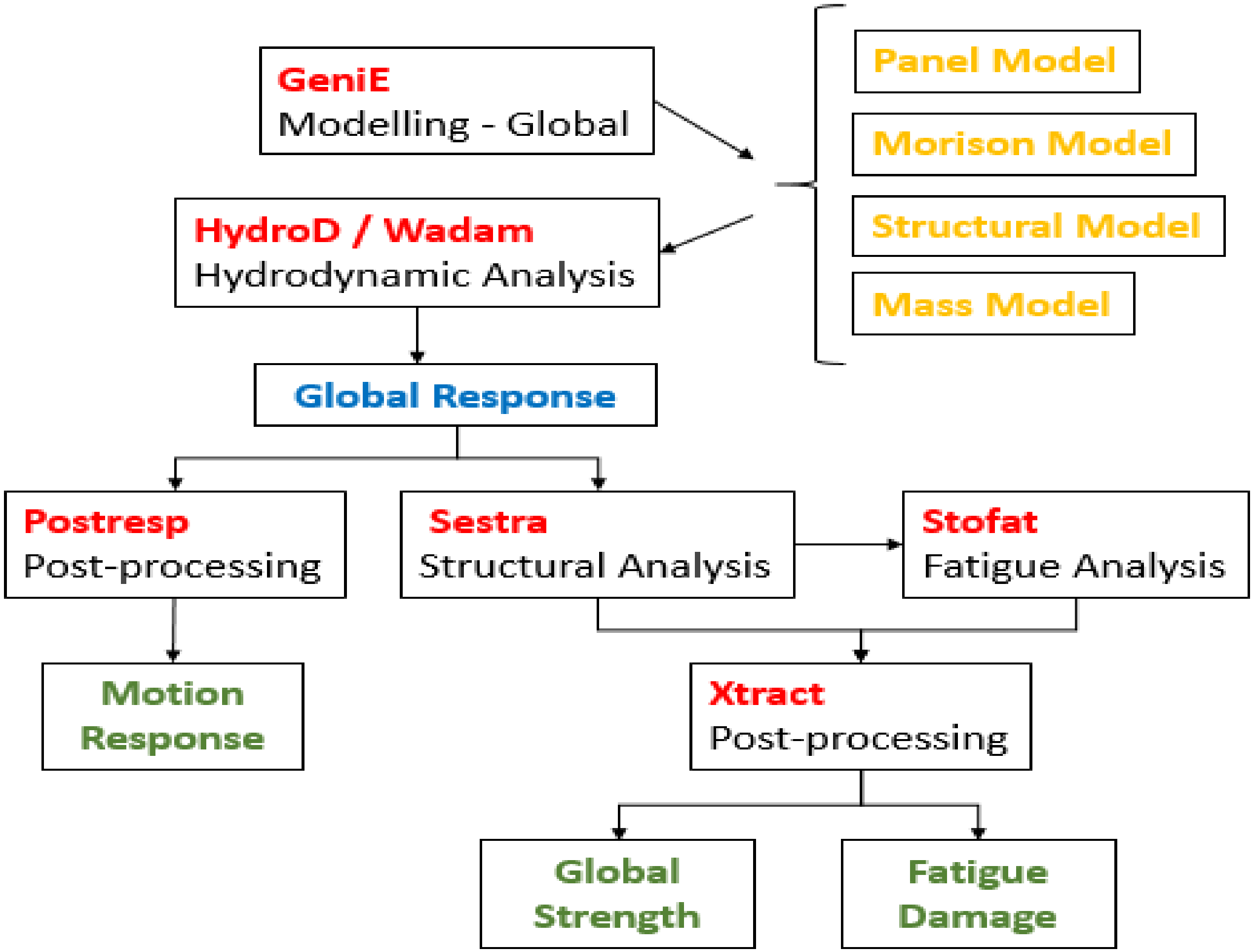
Scope:

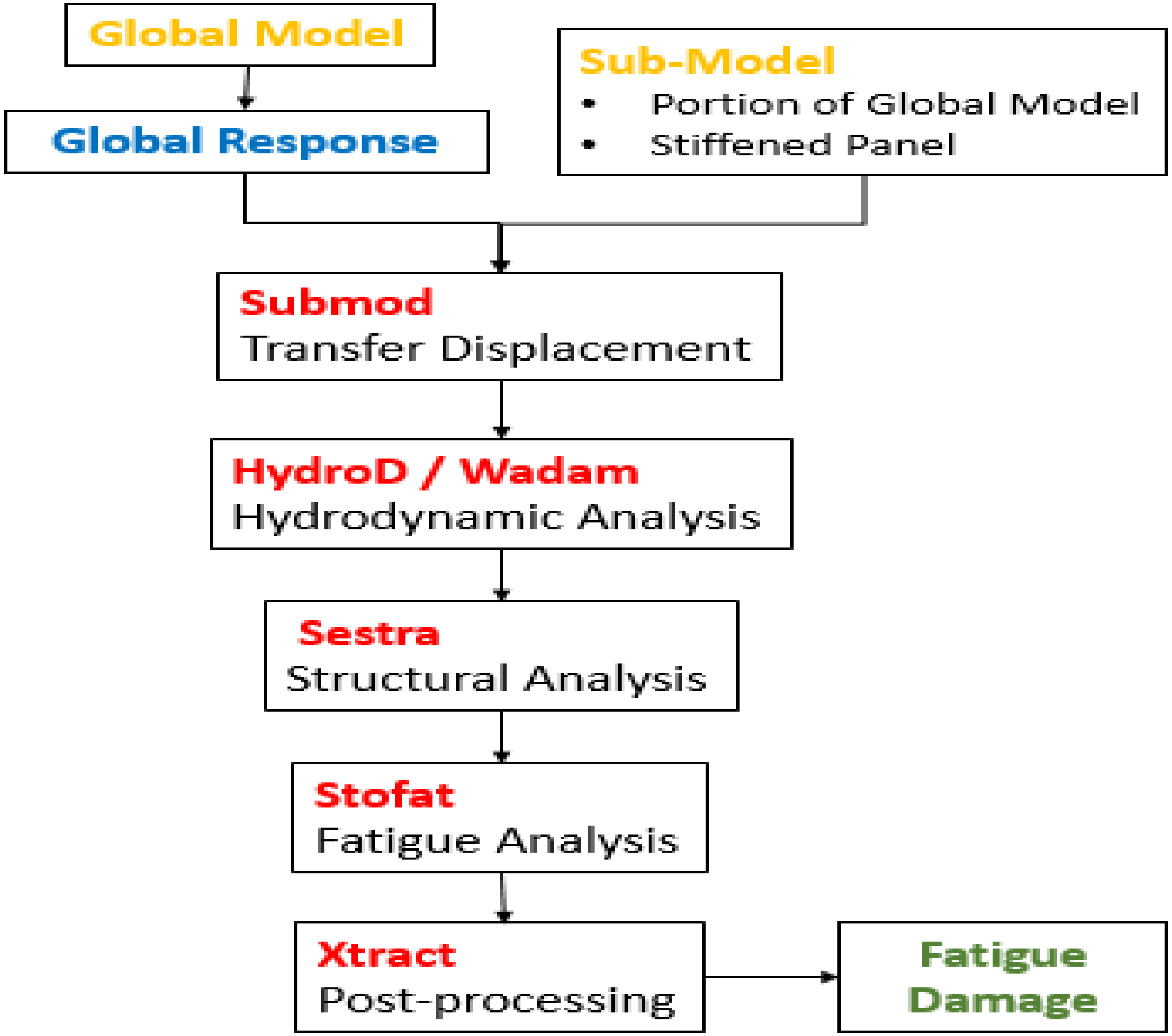
- Finite element model preparation and identification of the structure global responses and critical areas based on results of hydrodynamic analysis.

- Perform a quick fatigue screening based on class rule.

- Perform stochastic fatigue analyses using global and sub-models to estimate the fatigue usage factor and design life.

- Compare the possible differences in term of global responses and fatigue life for semi-submersible with and without sponsons.

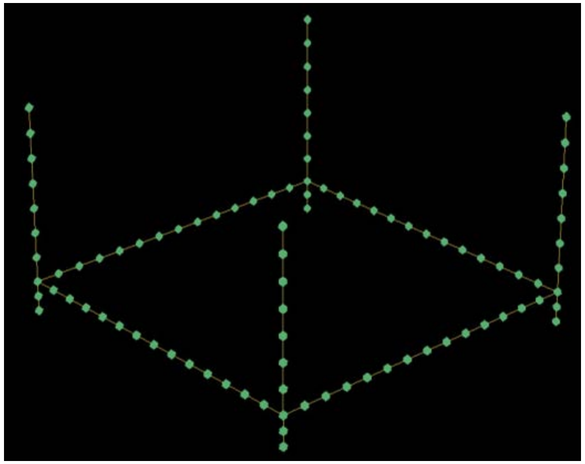

GeniE
Modelling - Global
Panel Model
Morison Model
Structural Model
Mass Model
HydroD / Wadam
Hydrodynamic Analysis
Global Response
Postresp
Post-processing
Sestra
Structural Analysis
Stofat
Fatigue Analysis
Motion Response
Xtract
Post-processing
Global Strength
Fatigue Damage



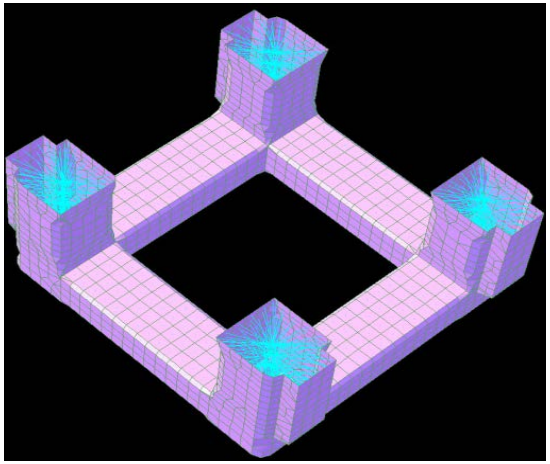
Sub-model Principle

*Transferring displacements from a global model to a sub-model

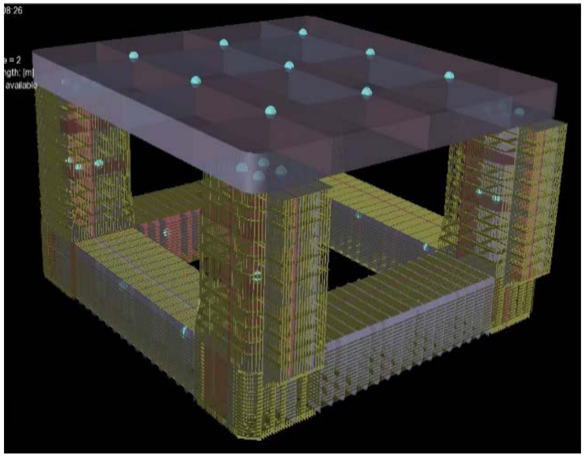
Morison Model



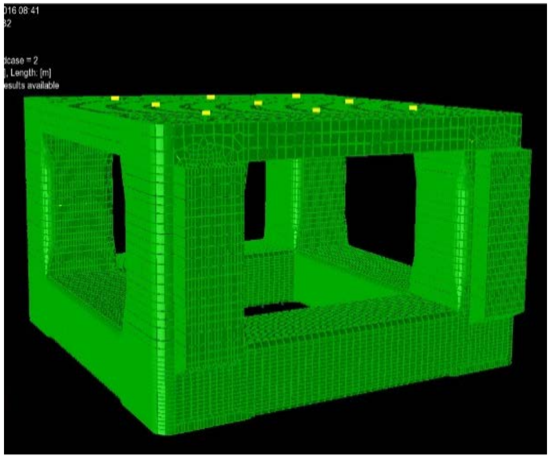
Panel Model

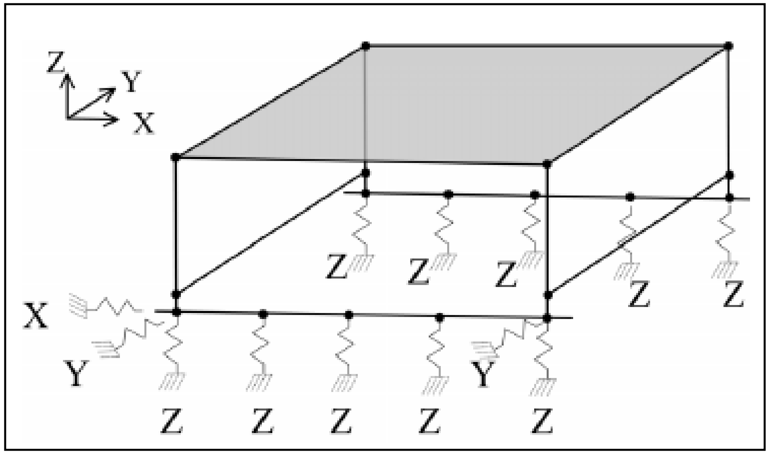


Mass Model
(With Load Distribution)



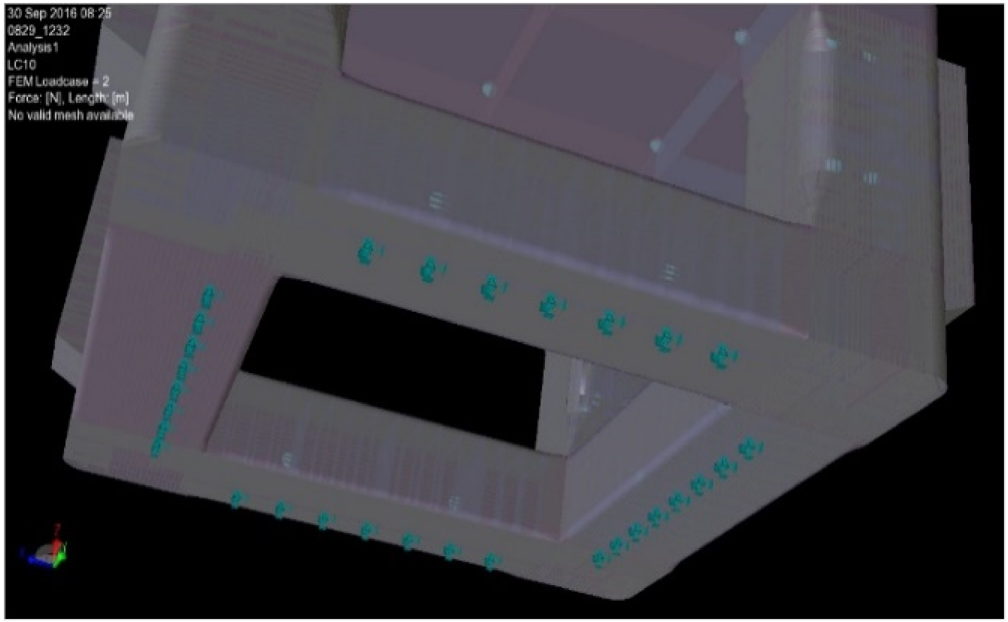
Structural Model
(In Finite Elements)





Statically undetermined boundary conditions.

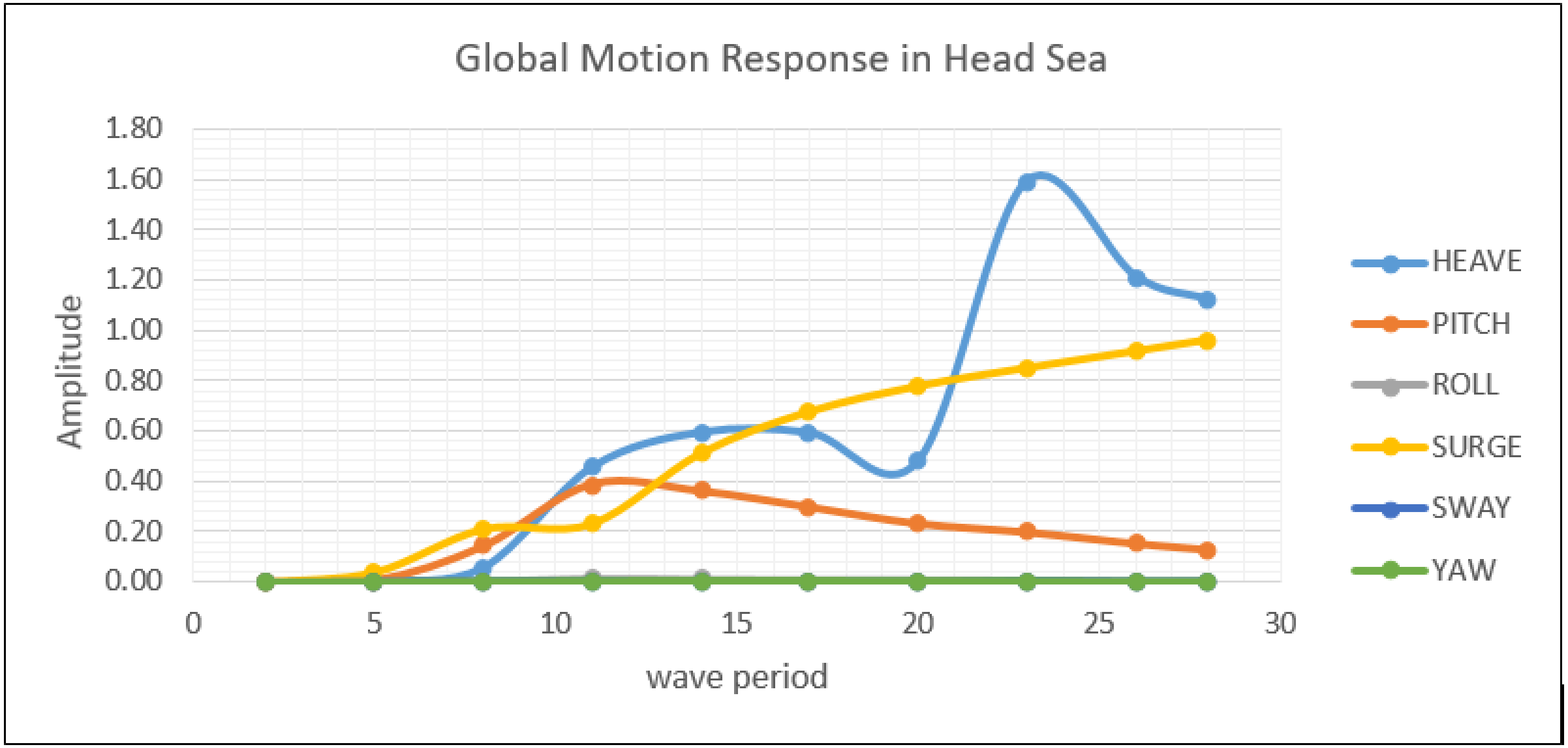
Springs to be located at strong points to limit the effect of reaction forces.



Vertical Spring Stiffness

$$k = \rho g A_w$$

*Horizontal Spring Stiffness is assumed as 1% of the vertical stiffness.



1. Yaw, sway and roll are almost negligible
2. Heave is the main governing response for rig design.
3. Maximum heave of about 1.6 and the period is about 23s.

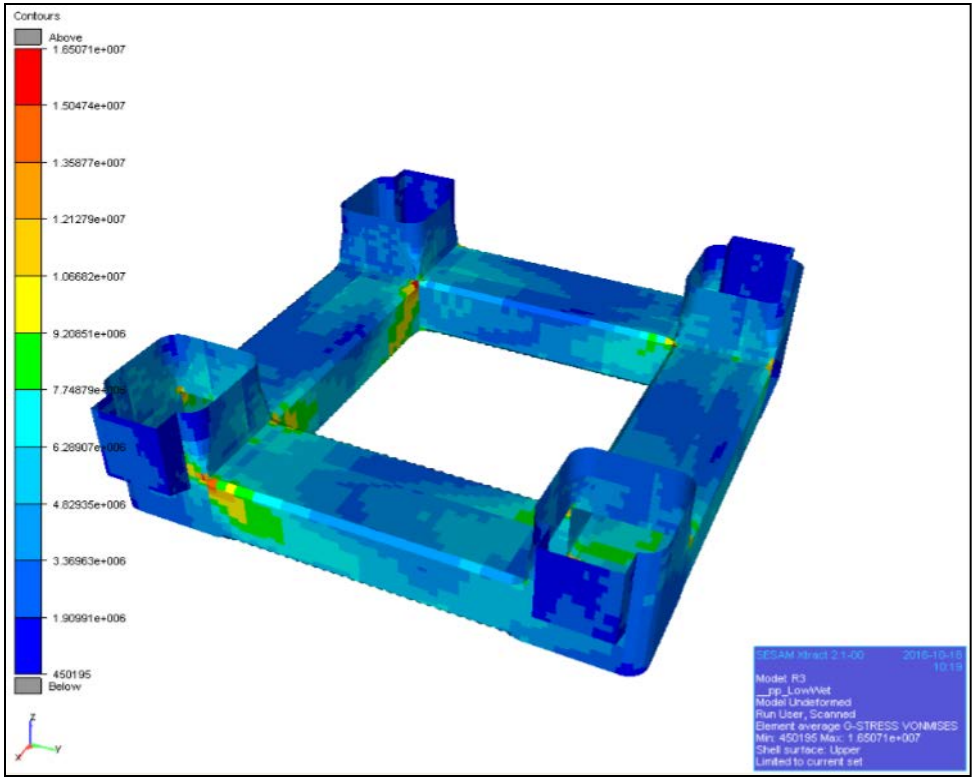


Table 10 Summary of von Mises stress distribution

No	Location	Stress Range (N/mm²)
1	Pontoon Top Plate	< 125
2	Pontoon Bottom Plate	<150
3	Pontoon vertical side shell near columns	< 200
4	Pontoon-Column connection point	<275
5	Column side shell facing inwards	< 225
6	Column side shell facing outwards	< 125
7	Sponson	< 100

1. Higher stresses are noticed on connection points between pontoon/column & adjacent side shells.

2. Relatively lower stresses on sponsons, top deck of pontoons and etc

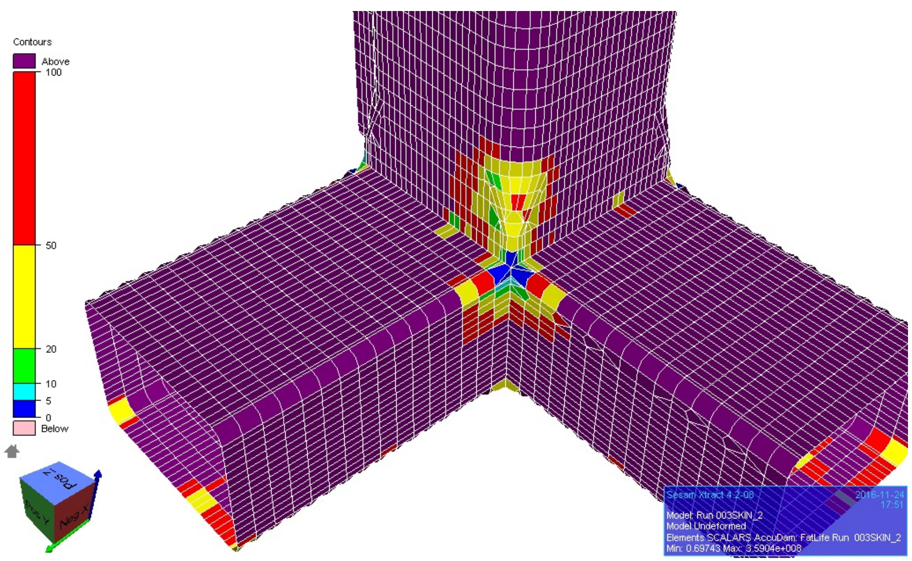
1. Based on example in DNV-GL RP-C203 Fatigue Design of Offshore Steel Structure, allowable extreme stress range for the model is estimated.
2. Design life of 20 years is assumed.
3. Using SN curve class-F, Weibull shape parameter of 1 and Design Fatigue factor (DFF) of 2.

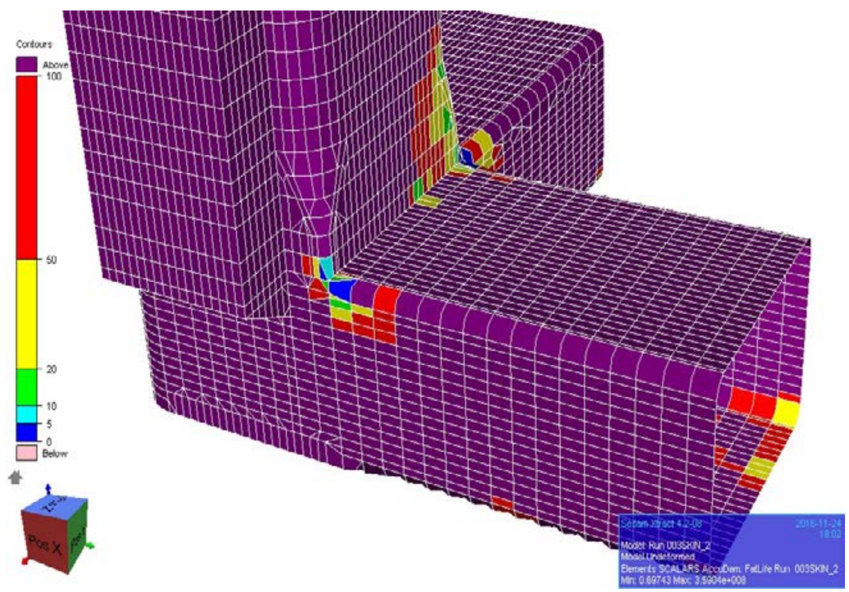
Table 14 Allowable stress for S-N curve class F with different Weibull parameter

	Weibull Parameter	0.8	0.9	1	1.1	1.2
	Reduction Factor on stress	0.847	0.853	0.858	0.862	0.864
	Allowable stress range during 10^8 cycles for components in seawater with cathodic protection	263.60	221.40	191.10	168.60	151.30
	Allowable stress for 25mm thick plate, N/mm2	223.27	188.85	163.96	145.33	130.72
		Allowable stress, N/mm2				
Plate thickness in mm	25	223.27	188.85	163.96	145.33	130.72
	23	227.97	192.83	167.42	148.39	133.48
	20	236.08	199.69	173.37	153.67	138.22
	18	242.38	205.02	178.00	157.77	141.91
	16	249.62	211.15	183.32	162.49	146.15

***Noticed that due to thickness effect, the weld allowable stress decreases if the thickness of load-carrying plate increases.

1. The selected 8 wave directions are from 0 to 315 degree with a constant 45° gap.
2. The contribution of each wave direction to overall fatigue damage is assumed to be the same.
3. Stofat build-in wave scatter diagram of North Atlantic Sea is used.
4. S-N curve type F for sea water environment with cathodic protection is used and the stress concentration factor is assumed to 1.0.

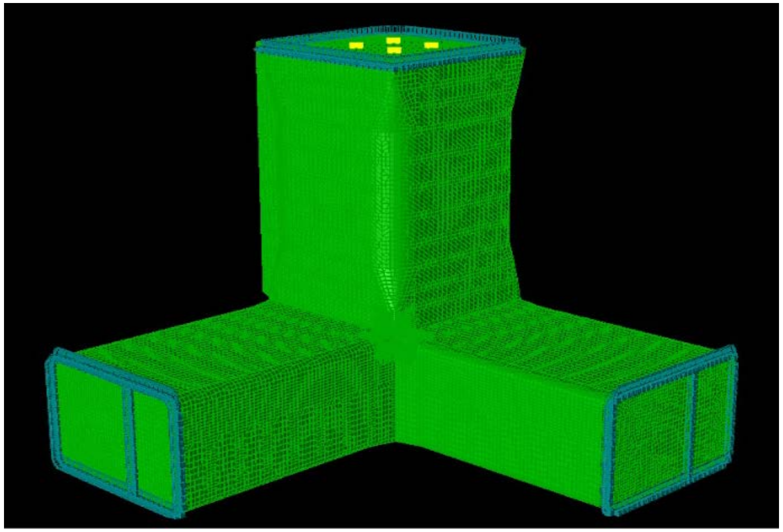


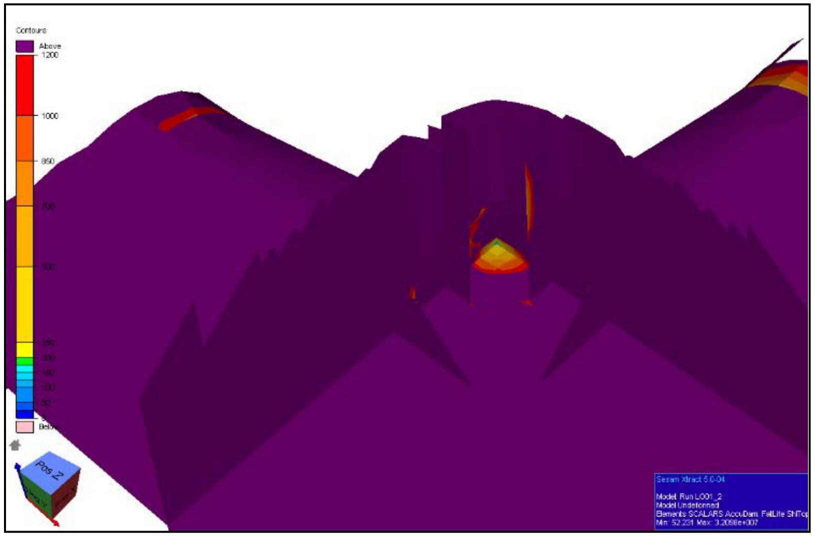


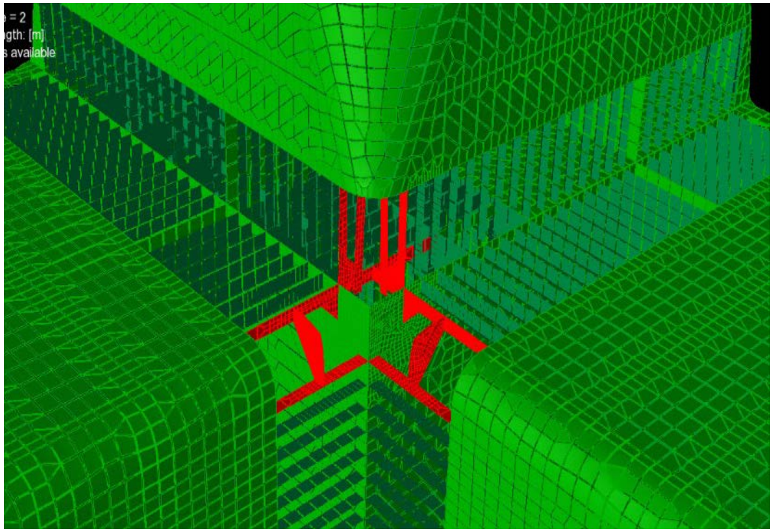
Sub-model

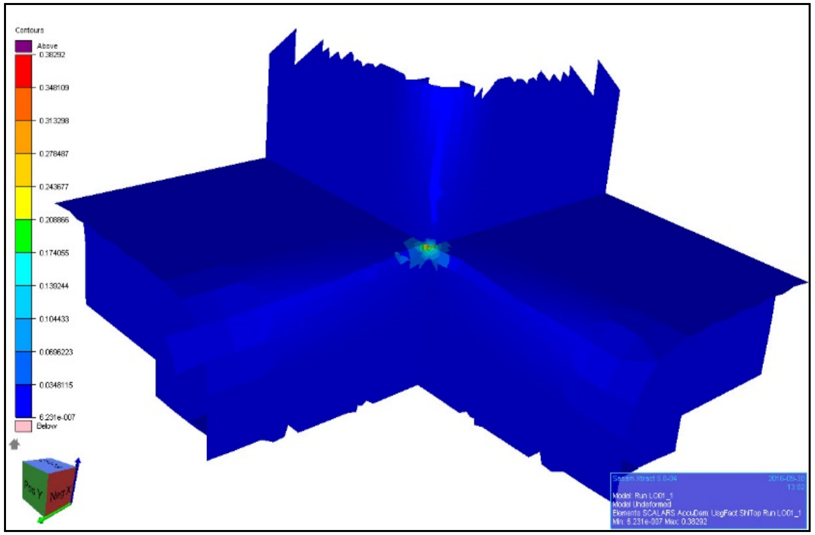
Mesh 0.1m for critical area. Rest - Mesh 0.5m mesh

Result

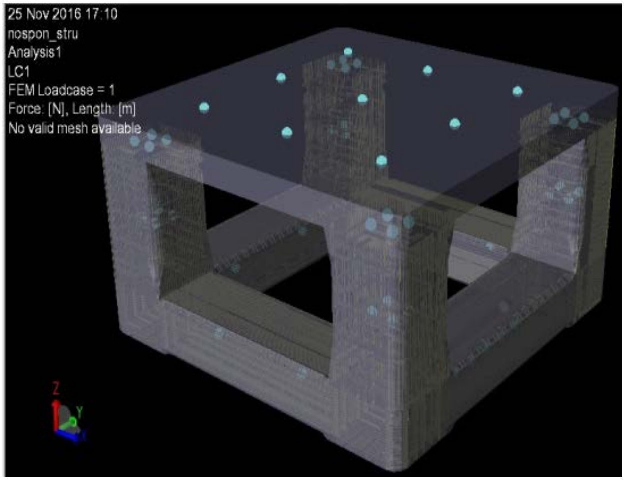


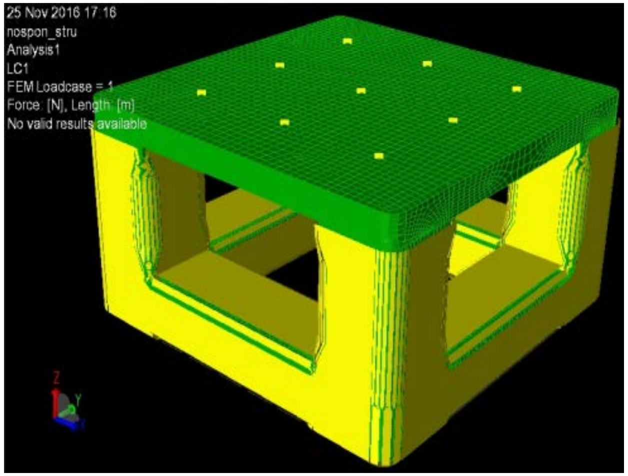


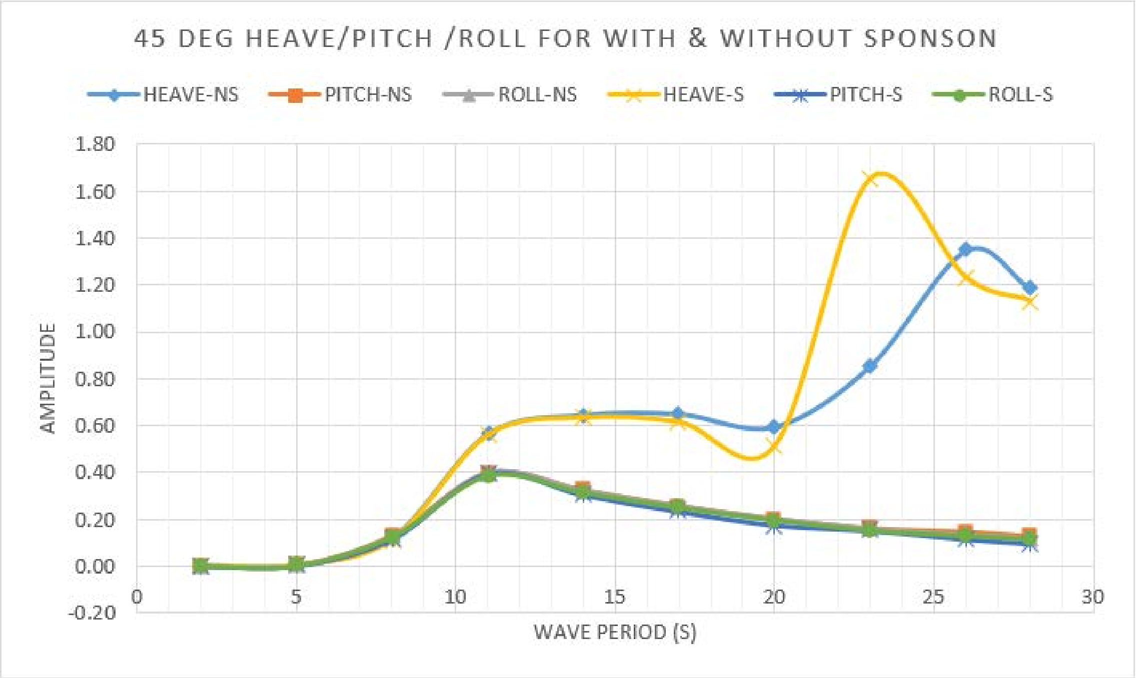




The model is modified by removing sponsons on four columns. All analyses are repeated to see the possible impact in term of global response, hydrodynamics and fatigue life.







The heave motion is somehow lower (1.35m) and the peak is shifted a few seconds higher when there are no sponsons attached to the columns.

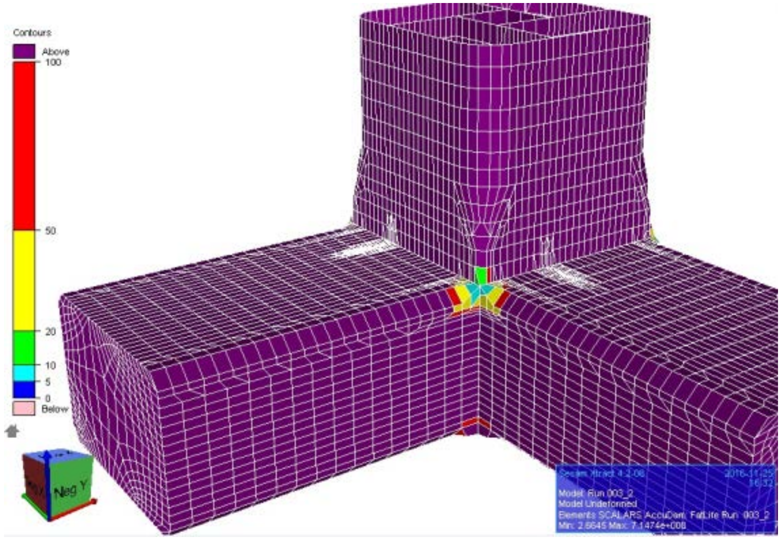
It is acceptable as the waterplane area is reduced the heave period is increased.

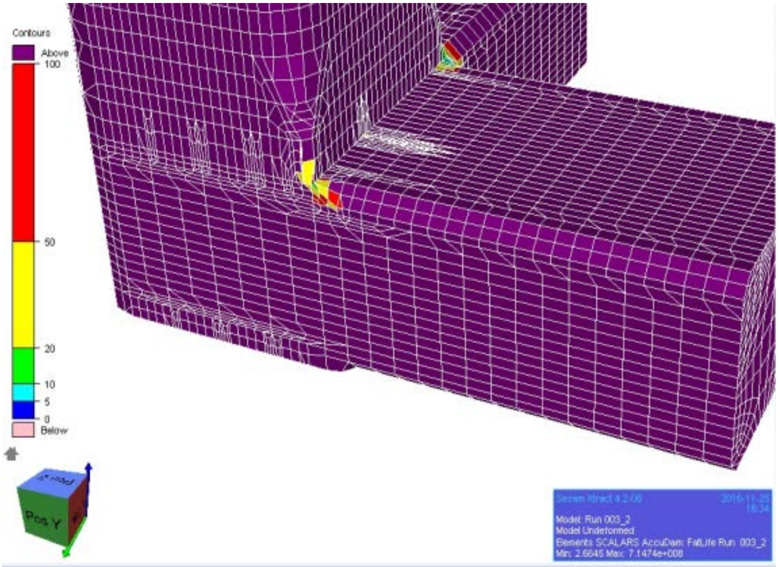
1. Sponsons are usually added to increase the payload capacity of a semi-sub by increasing the buoyancy. Sponsons can be in many different forms.

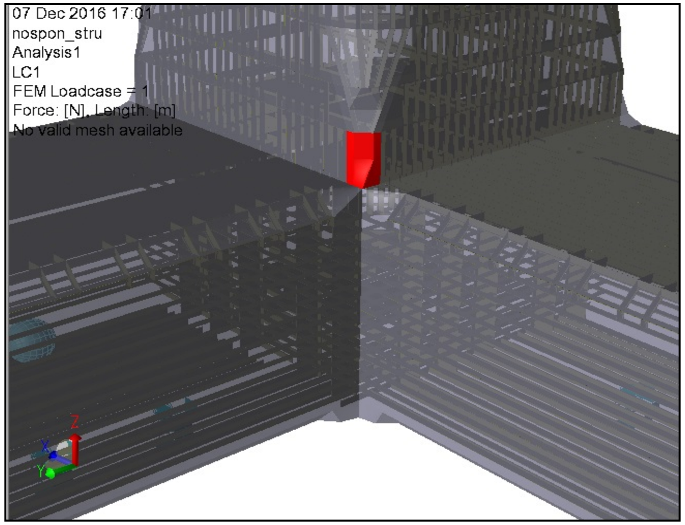
2. Results show that the areas vulnerable to fatigue damage are not much different after the removal of sponsons.

3. With stress concentration on pontoon-column connetion facing inwards and on the side shells that facing outboard.

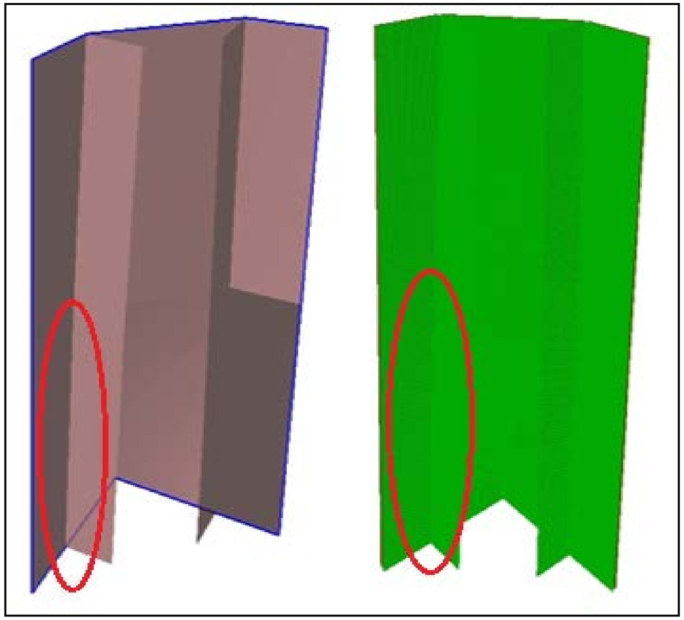
4. Analyses are repeated using sub-model

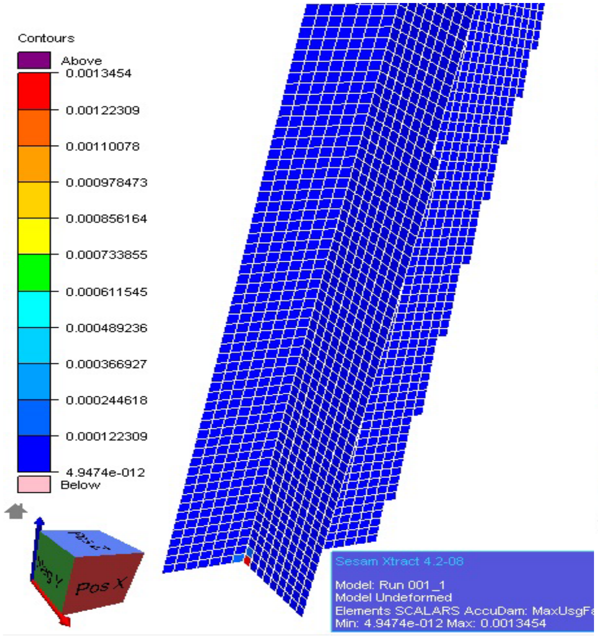


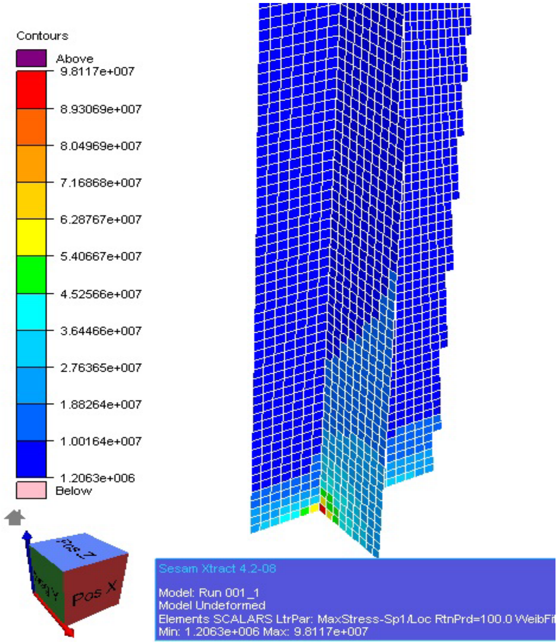


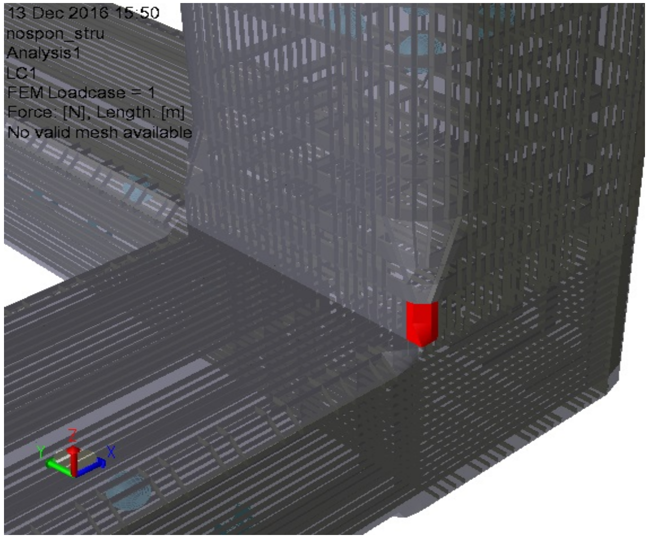


- Extra check is performed on critical areas.
- FE sub-model with mesh size of 1cm x 1cm is generated.
- The sub-model plate thickness is 25mm and the stiffener is bulb flat 280*12t.
- The mesh elements used are with about 0.4* plate thickness.
- Results below. (mid) Fatigue usage factor (right) 100-year max principal stress.

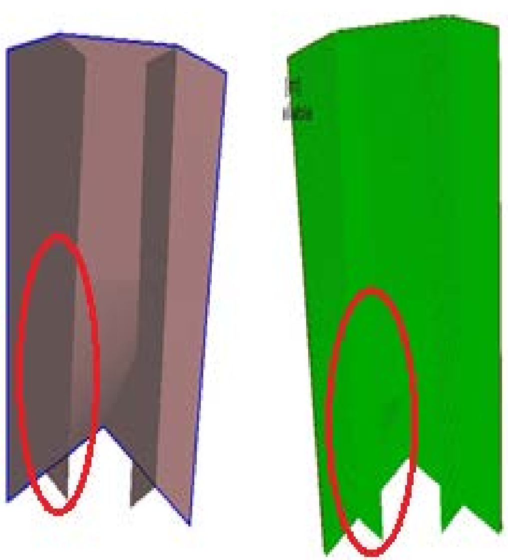


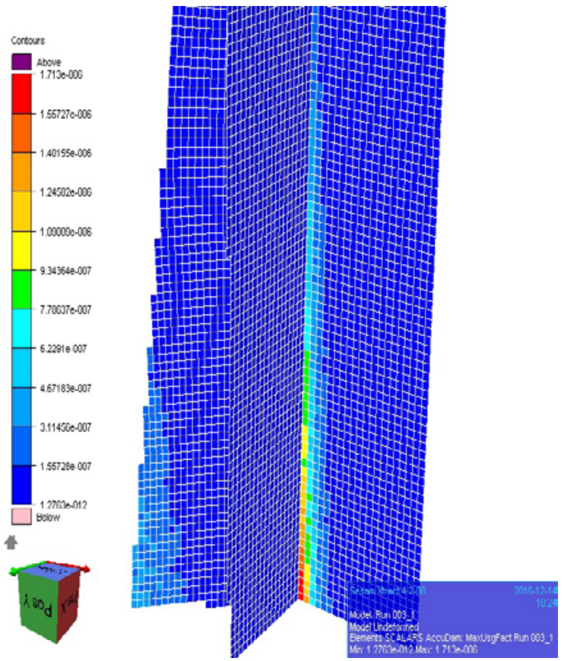


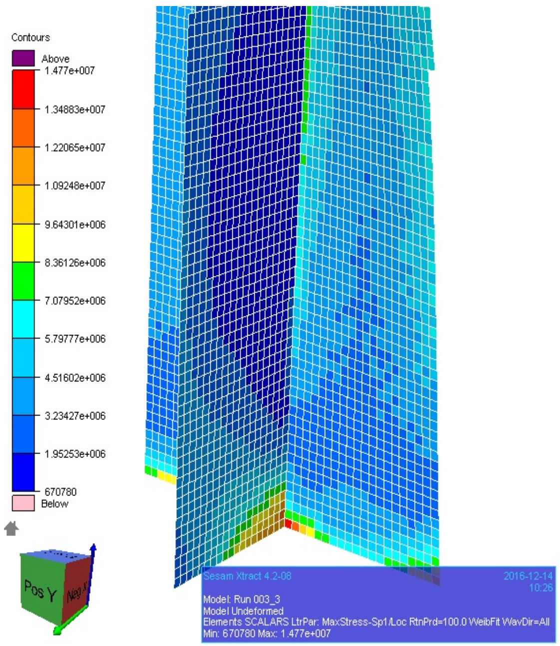




- Results below. (mid) Fatigue usage factor (right) 100-year max principal stress.
- Noticed that the fatigue usage factor is low and the sub-model is with sufficient design life.







Conclusion

1.Finite Element models are used as inputs for global responses, hydrodynamic and fatigue analyses.

2.From the global responses analyses, the maximum heave is found to be about 1.6 and the period is about 23 second.

3.Hydrodynamic analyses and quick screen fatigue check based on DNV-GL example is performed to find the critical areas and estimate the allowable stress range for the required design life of 20 years. Sub-model Results show that the fatigue design life for the pontoon-column connection points is actually sufficient to meet the design life required.

4.Based on the results, the stress distribution and concentration areas are almost the same, either with and without sponsons installed. The fatigue design life of the vessel after the removal of sponsons is sufficient.

Recommendation

1.More detailed analysis with ballast and mooring loads considered.
2.Detailed structural model.
3.Wave period and directional probability.


Thank you!
STOCZNIA GDAŃSKA