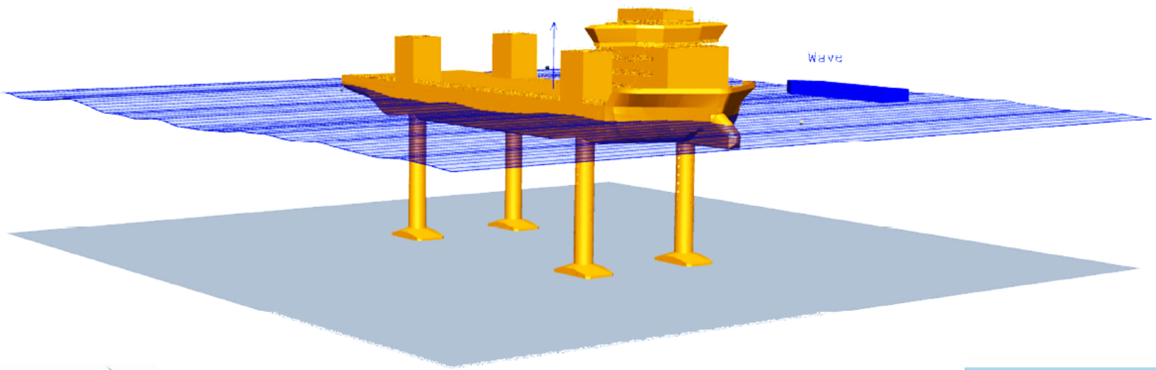
17th DNV GL Workshop - TUHH

Global Response Analysis of Wind Turbine Installation Vessels in Semi-submerged Condition. A Modified Quasi-Static Approach



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EMship Advanced Design

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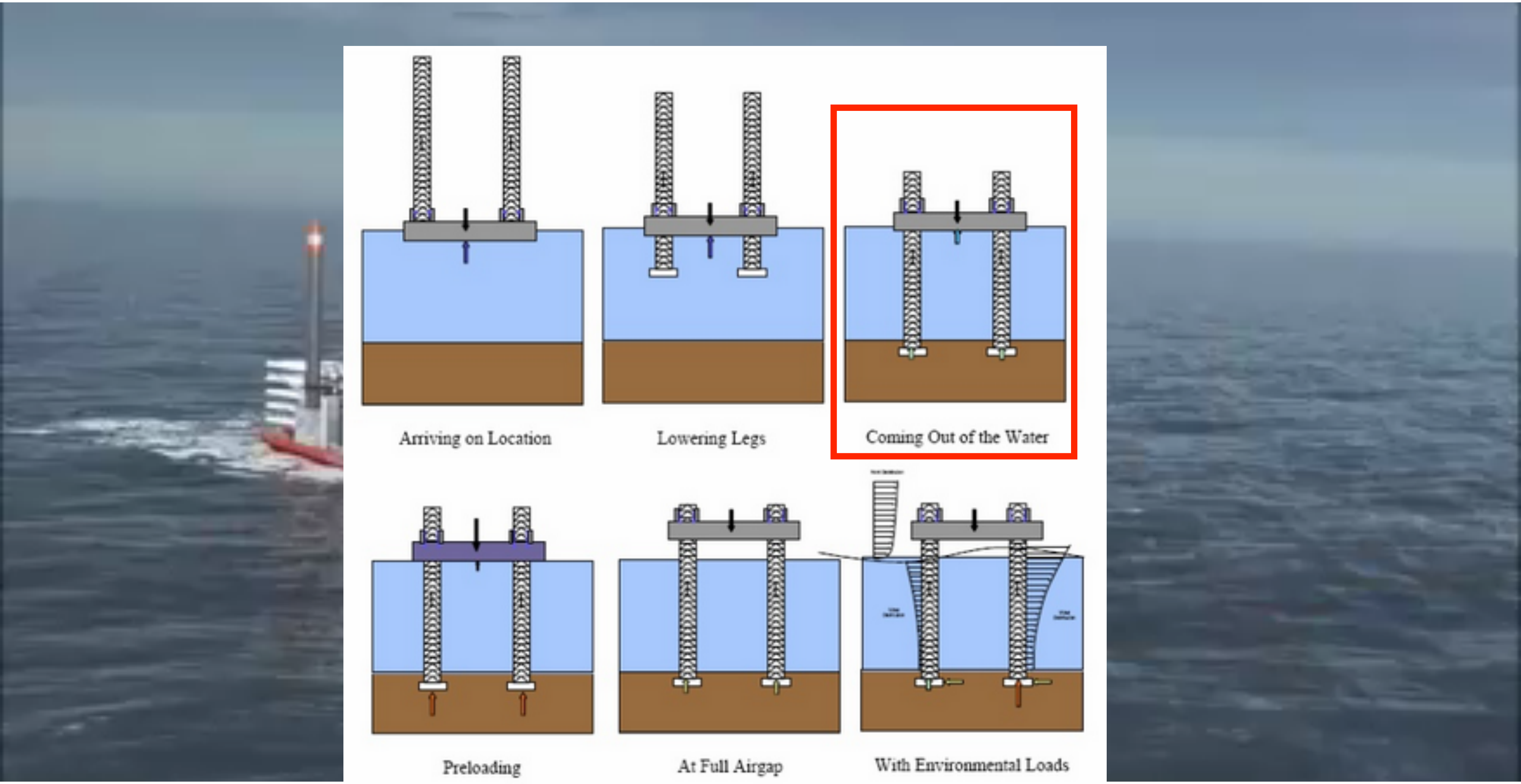
Introduction to WTIV



SWIRE PACIFIC OFFSHORE- Swire Blue Ocean – Fred Olden Wind Carrier

Motivation of the study

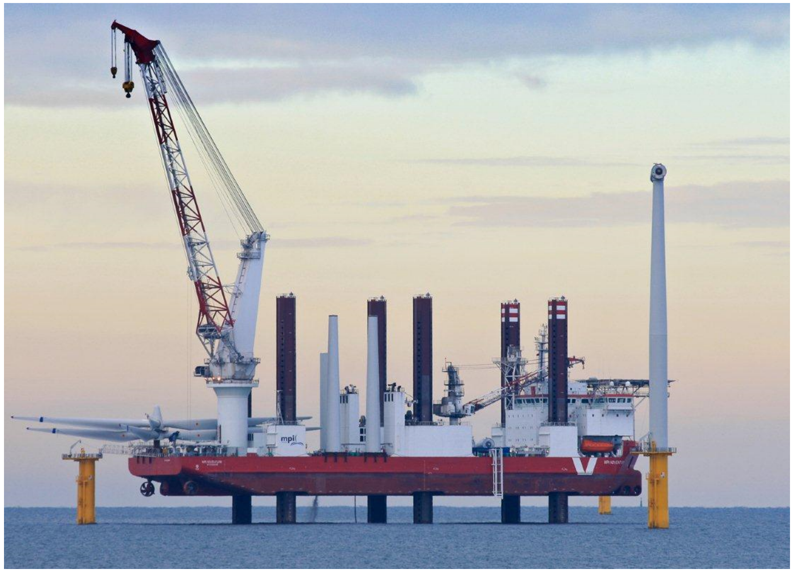
Common design load case is the called "Survival Condition" (major jack-up system elements, leg components, leg-hull connection elements...)

However, the offshore *industry had seen many failures during transient phases* mainly while "Semi-submerged".

Semi-submerged condition is not covered by class requirements or well documented by ship design offices.

Objective

Uncover the importance of this o.c. in the design process of self-elevated jack-up vessels, done by a quantitative load estimation analysis.



Agenda

1. Physical variables in WTIV
2. The Global Response Analysis
3. Case of Study
   - Considerations
   - Verification of dynamic effects
   - Comparison of operational conditions
   - Effect of wet surface in drift and vertical loads
4. Remarks

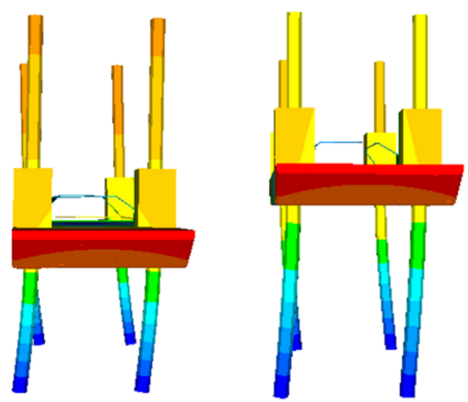
1. Physics of a WTIV

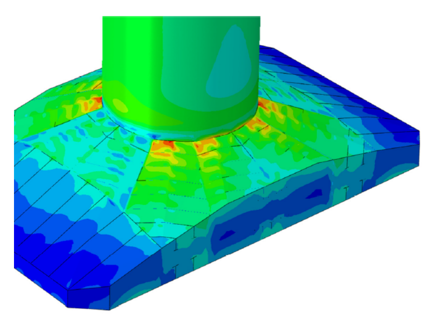
Multiphysics problem

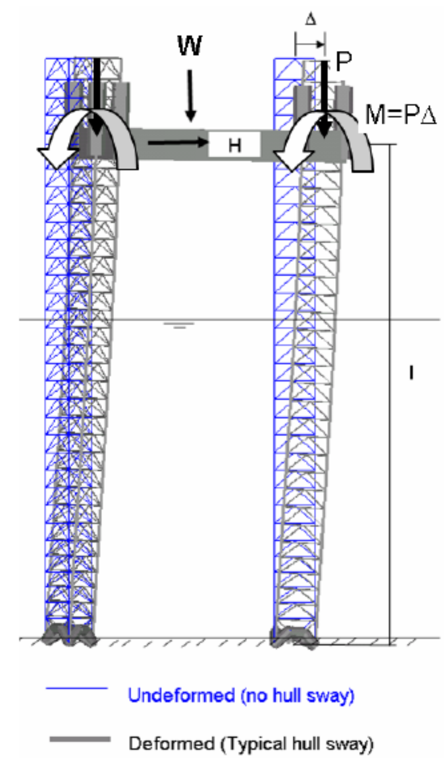
- Wave & current Loads
- Fluid-Structure Interaction
- Wind Loads
- Non-linear struc. response
- Soil-Structure Interaction
- Dynamic effects

Results in:

- High non-linear effects
- Large hull displacements
- Load increments in base reactions
- Stress increment in jack-up system, leg, and leg-hull connections







<u>Complex models needed for realistic analysis.</u>

2. Global Response Analysis

Coupled FEA with CFD Simulations. This is for SSI & FSI consideration. (DNV-GL softwares)

- Wave loads acting are determined by CFD techniques.
- Hull motions, base reactions and stress distribution are determined with FEM considering loads from CFD simulations.

METHODOLOGIES

Deterministic	Stochastic
Non-linear, Dynamic	Non-linear, Dynamic
Linear, Dynamic	Linear, Dynamic
Linear, Static	Linear, Static

Accuracy

2. Global Response Analysis

Key issues?

- High non linear structural effects and non-linear foundation.
- Lateral flexibility affected by the leg footing and the soil foundations. *Pinned, Fixed, Elastic Foundation model?*
- Foundation models are commonly high-non linear (large time domain simulations required)
- Every analysis is particular, *which input is the correct?*
- Non-linearities not well represented by model-tests due to scale effects
- Result validation difficult in the reality

For physics understanding:

Assumptions:

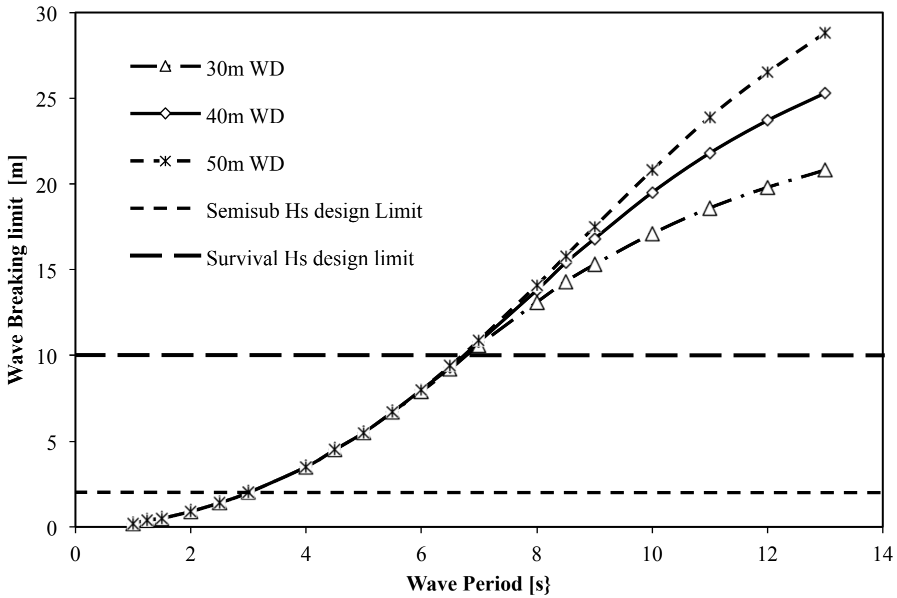
- Deterministic linear, quasi-static approach with Dynamic Amplification Factors (Inertial horizontal force method).
  - Wave loads: 3D linear potential flow (Diffractive potential – Panel Method) combined with Morison formulation for inertial and drag force estimation. (No sloshing)
  - Non-linear structural analysis using second order FE for global structural analysis. (Based on DNV GL FEM class guidelines)
  - Simplification of SSI by constrains in legs (Pinned boundary condition without spudcan modeling).

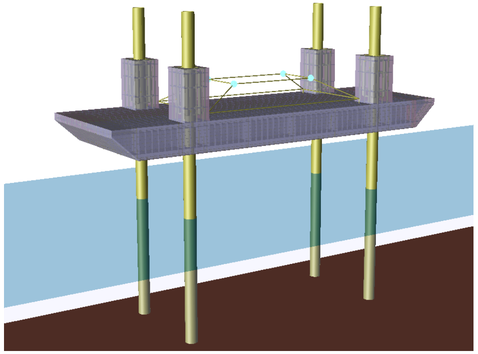
Scope

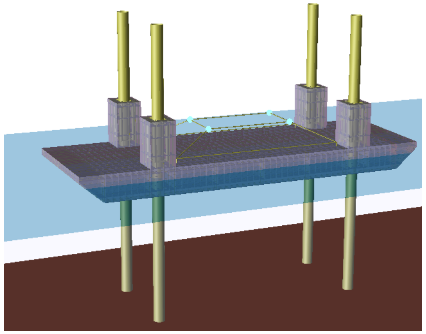
- Stiffness and structure flexibility representation
- External load estimation
- Hull center motions
- Base reactions & Overturning bending moments

Considerations

Length overall	120	[m]
Beam	42	[m]
Depth	9,5	[m]
Tonnage (NL)	9797	[tons]
Gross Tonnage (L)	14797	[tons]
Drat	2,52	[m]
Air gap	10	[m]
Soil Penetration	5,5	[m]
H Max, Semi-Submerged	2	[m]
H Max, Survival	10	[m]
Wave Period Range	0-13	[s]
Current Velocity	5	[m/s]
Wind Speed	0	[m/s]
Hull Inclination	0	[°]
Water Depth (WD)	30-40-50	[m]
Number of legs	4	[unit]
Leg Length	100	[m]
Leg Diameter	4	[m]







Case of Study. 1

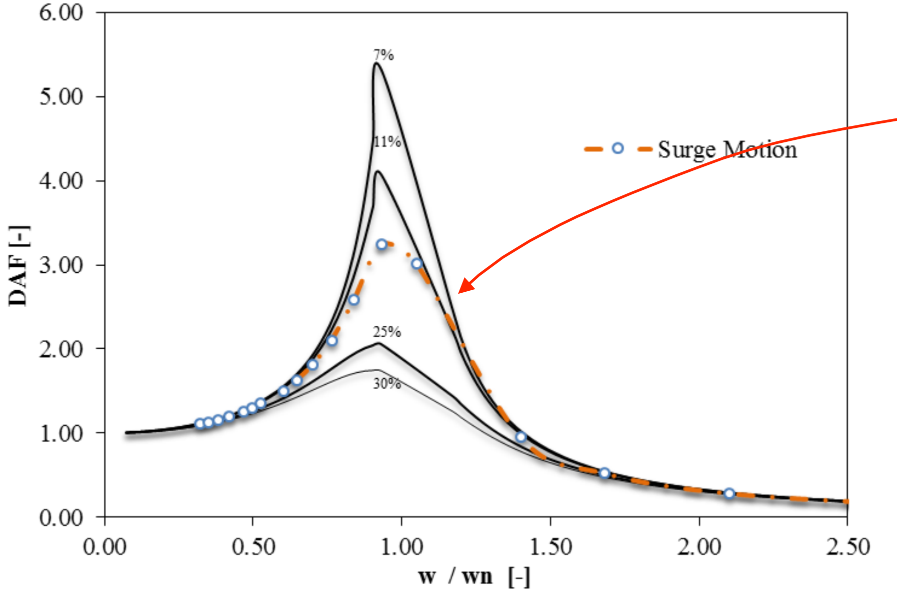
Dynamics, significant while S.S?

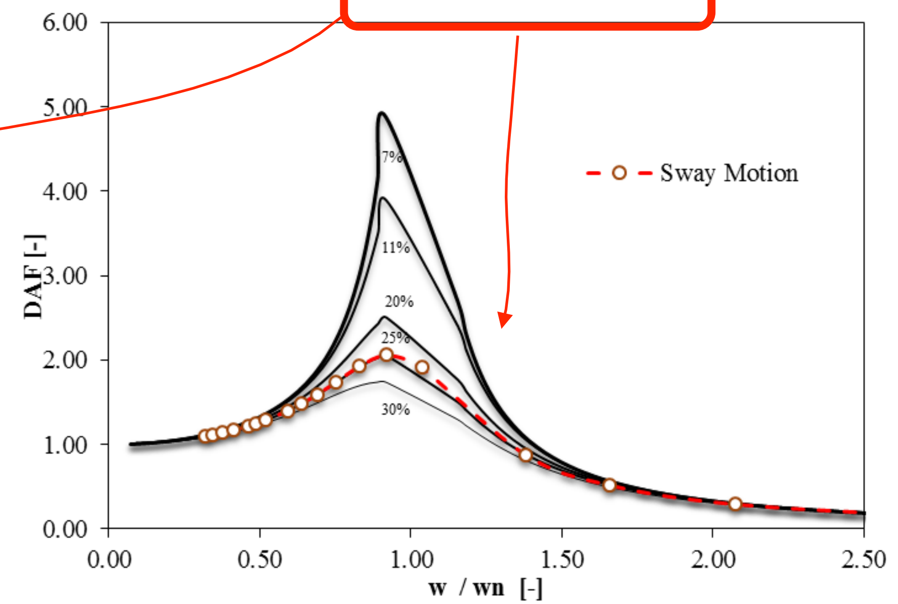
Case of Study. 1

Operation: Semi-submerged. Dynamics, significant?

Quasi-static Vs Dynamic Analysis, 2 headings, 50m WD

DNV- RP-C104





Surge amplified by 3.5

Sway amplified by 2

Case of Study. 1

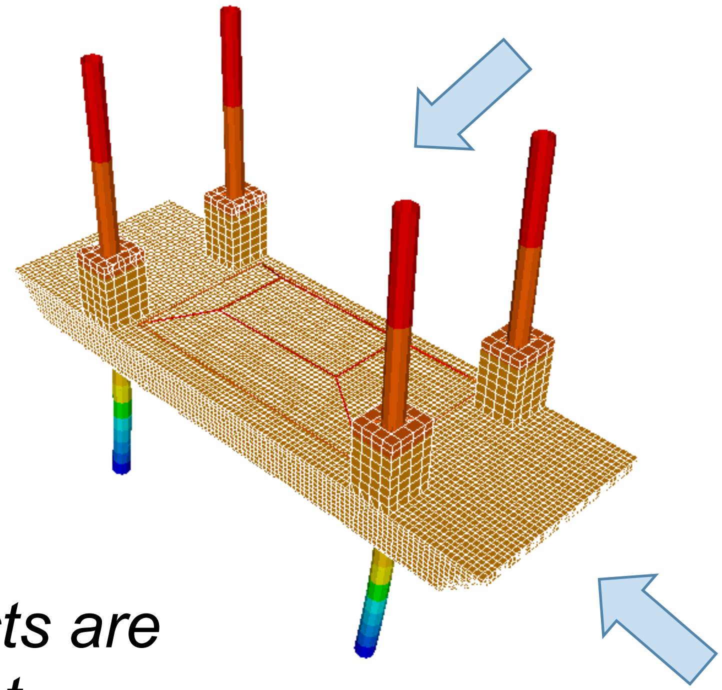
Operation: Semi-submerged. Dynamics, significant?

Quasi-static Vs Dynamic Analysis, 2 headings, constant WD

Max. DAF

Heading	Base Shear	Vertical Force	Overturning Bending
90°	1.79	1	1.79
180°	2.07	1	2.07

Heading	Hull Drift
90°	2.11
180°	1.99



Dynamic effects are significant

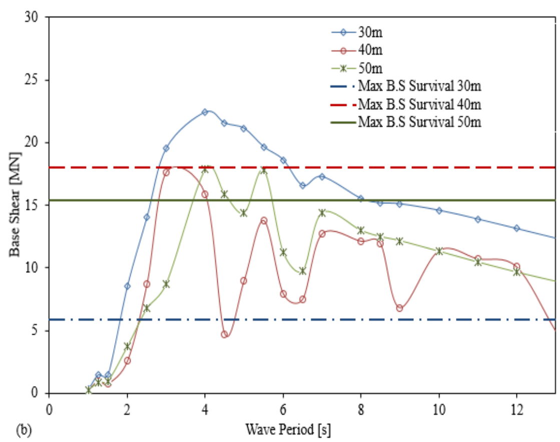
Case of Study. 2

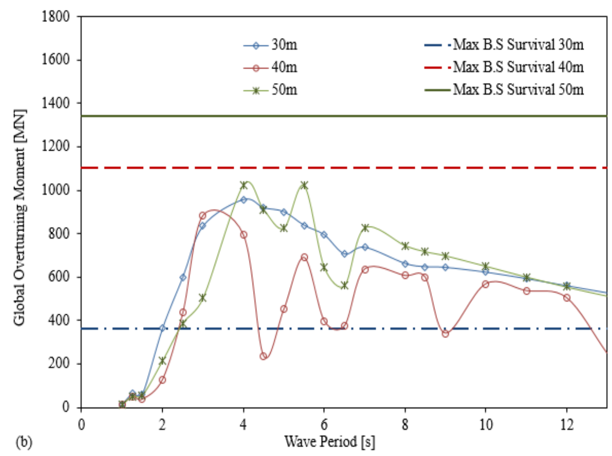
Semi-submerged Vs Survival (Elevated)

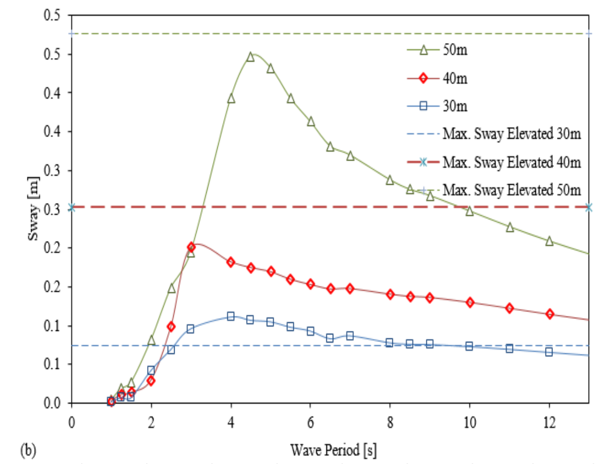
Case of Study. 2

Operation: Semi-submerged vs Survival

Comparison of Max. Loads. 3 WD, 2 headings







<u>Semi-submerged exceeded max values</u> registered during elevated condition for lower water depths, specifically for beam seas.

Justified mainly by low inertia of structure in lower water depths. Rotation point on the seabed.

Case of Study. 3

Case of Study. 3

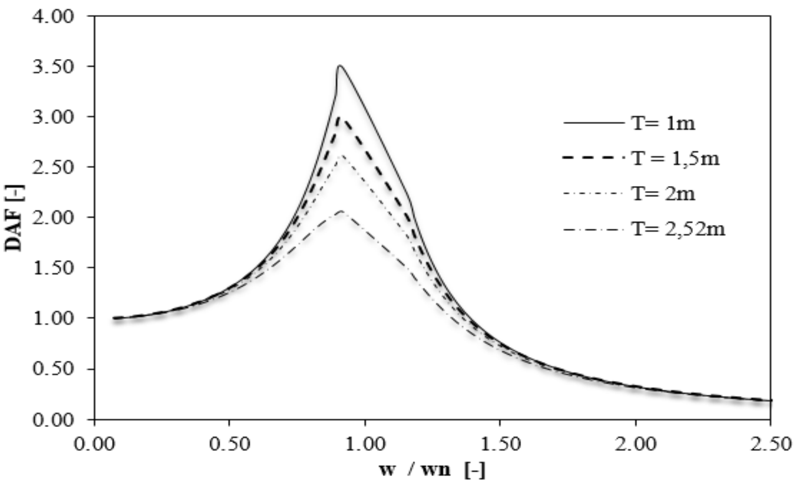
Operation: Wet area effect in vertical loading

3 WD, 2 headings, 4 leg uniform pre-loading.

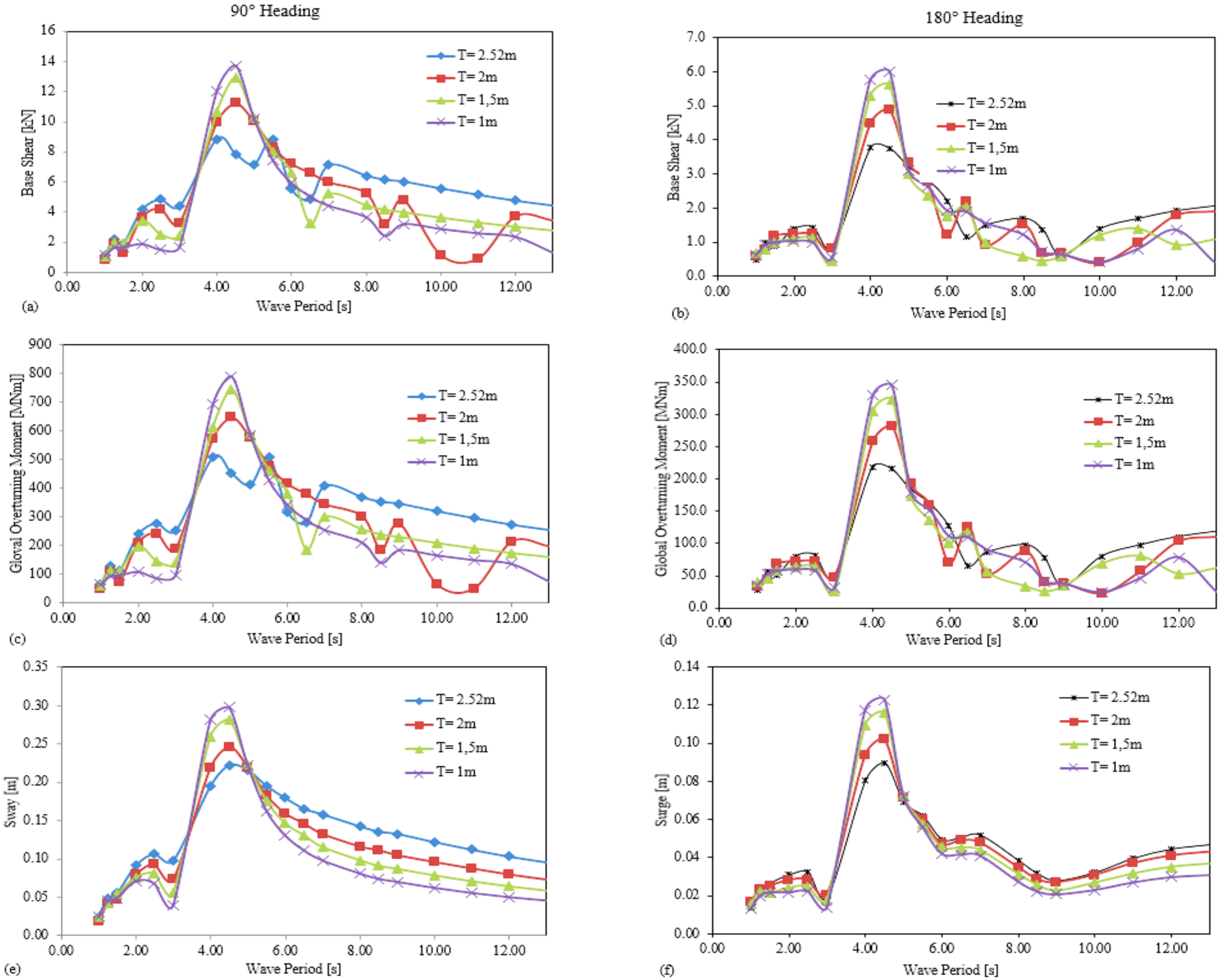
Draft [m]	Leg Pre-loading
2.52	0.00%
2	34.52%
1.5	35.72%
1	52.30%

Draft	Hull Area Reduction	
	90°	180°
[m]	[%]	[%]
2.52	0.0%	0.0%
2	27.7%	20.6%
1.5	29.0%	40.5%
1	47.3%	60.3%

Draft	Drift Force Reduction	
	90°	180°
[m]	[%]	[%]
2.52	0.0%	0.0%
2	27.4%	14.6%
1.5	45.5%	44.6%
1	61.1%	48.9%



Case of Study. 3



Overall damping decreases and wave loading decrease significantly.

Besides that, *resonance effect will* generate slight *increments* in the *loads and displacements close to NF.*

Remarks and Conclusions

This first approximation reveals new possible risk scenarios that should be considered as class requirements for designers and ship owners.

Dynamic effects are expected to be significant in S.S condition with a simplified approach. More exhaustive analysis should be performed (Non-linear, Dynamic, Deterministic or Stochastic)

S.S condition can present significant load increments in low water depths exceeding common design load cases even at lower wave heights.

Large hull displacements and loads are expected that if considered, will redefine major jack-up, leg and hull connection element design.

Full characterization of vessel response should be performed to decrease risk during operation

Further analysis and application to real cases are needed to validate results due to model simplifications.

Thank you for your attention.

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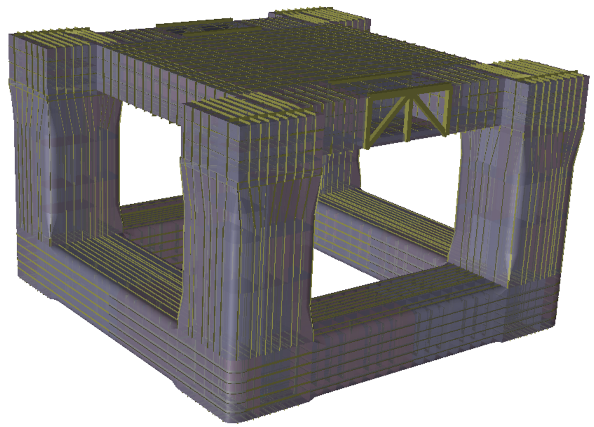
Fatigue Analysis of a Tension Leg Platform: Fatigue Life Improvement



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Methodologies proposed

- Design details to reduce stress and strain concentrations
- Avoid welding in areas where low ductility or fracture toughness steel is (e.g. K areas of wide flange members, corners of hollow steel sections)
- Provide adequate protection from the environment (e.g. provide measures to prevent galvanic action between dissimilar metals)
- Increase the thickness of the critical area
- Improve surface conditions
- Improvement of fatigue life by fabrication: Grinding, TIG dressing and Hammer peening
- Use of high-performance alloys resistant to corrosion fatigue
- Etc

Objective

Quantify fatigue life improvement of certain structural modifications

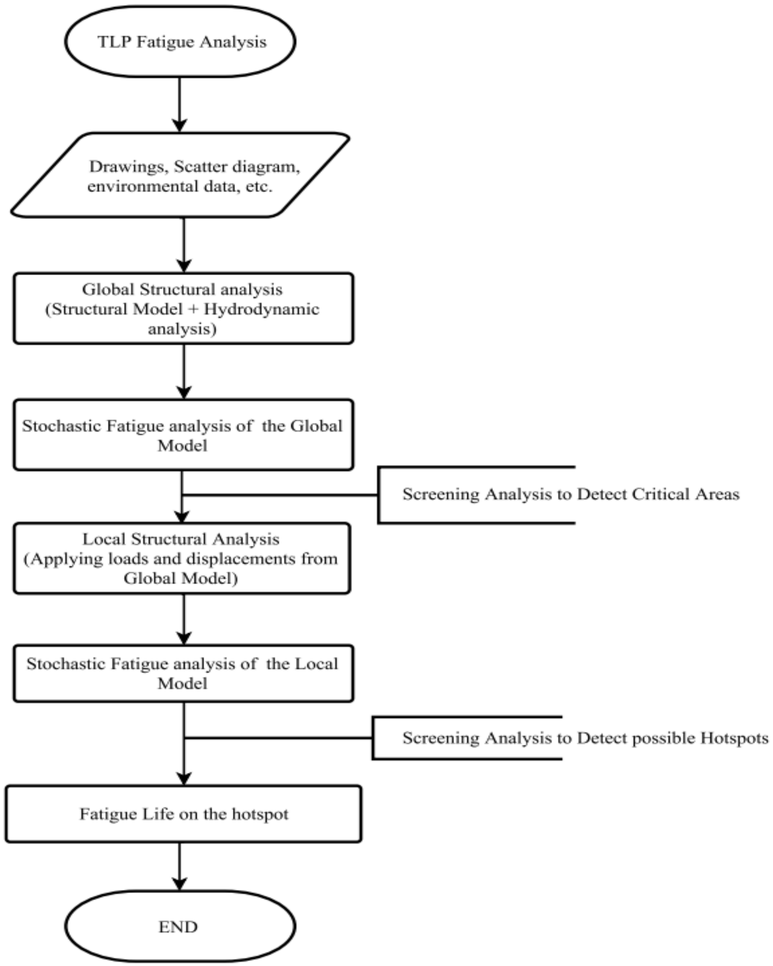
Motivation

Leads to a lower number of design iterations

Agenda

1. Methodology
2. Scope of work - Assumptions
3. Case of study
4. Analysis
5. Results
6. Conclusion and future work

1. Methodology



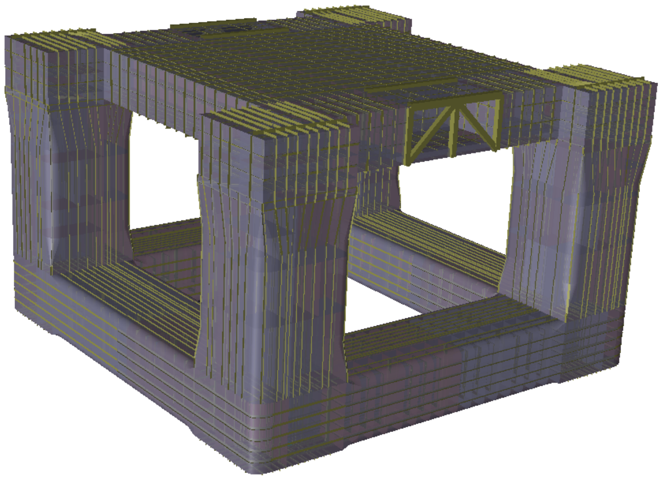
2. Scope of work

- Structural model developed by finite element method
  - Global model
  - Local model
- Hydrodynamic analysis performed in the frequency domain:
  - 3D panel method to evaluate velocity potentials and hydrodynamic coefficients
  - First order velocity potential -linear wave loads
  - Drag forces are determined using Morison formulation
- Quasi-static analysis of the structural response for the global and the local models
- Stochastic linear fatigue analysis based on S-N data
- Effects of thickness´s increments in critical areas

3. Case of study

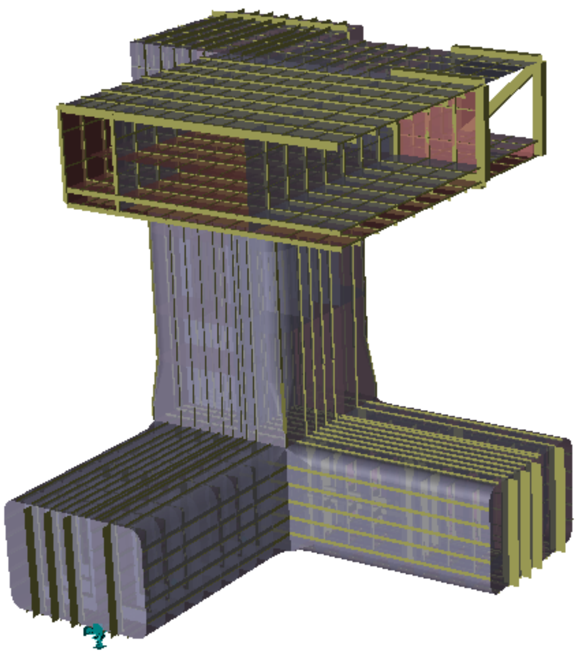
- Full-size TLP composed by four columns connecting pontoons
- Operational area: North Sea, which a water depth of 327.5 m
- Main Dimensional Parameter:

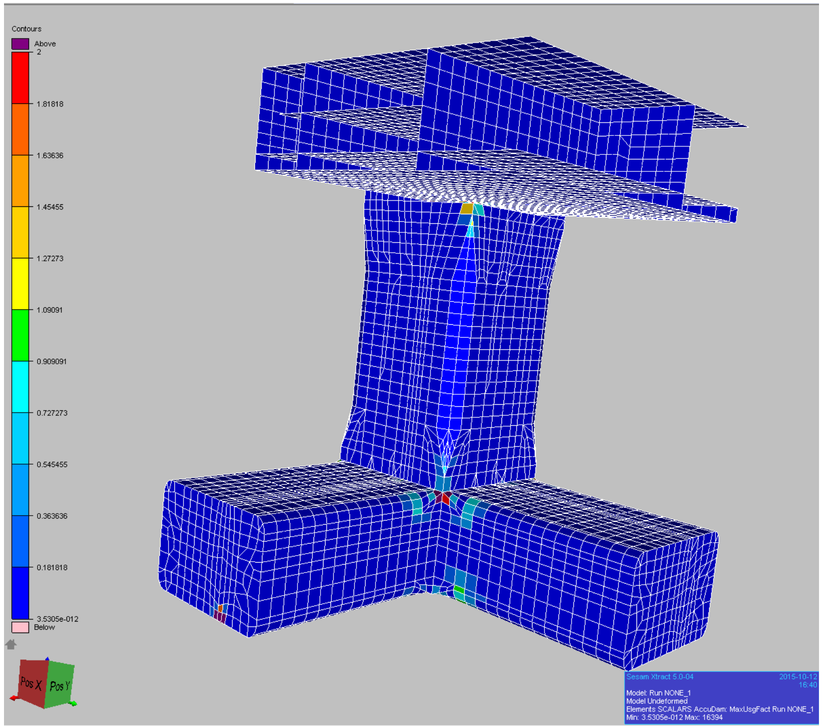
Length overall	85 m
Beam	85 m
Depth	54 m
Draught	27.5 m



4. Analysis

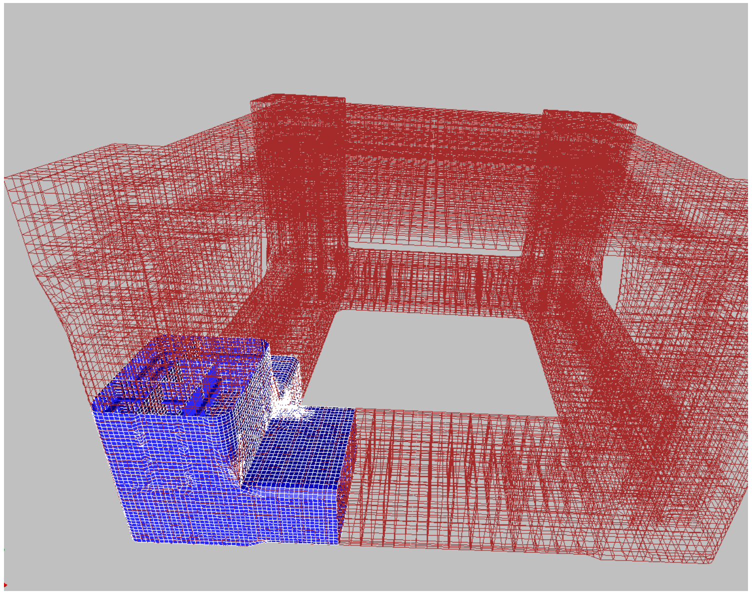
- The structure present a symmetry respect the axis X and Y
- Results are presented in form of usage factor

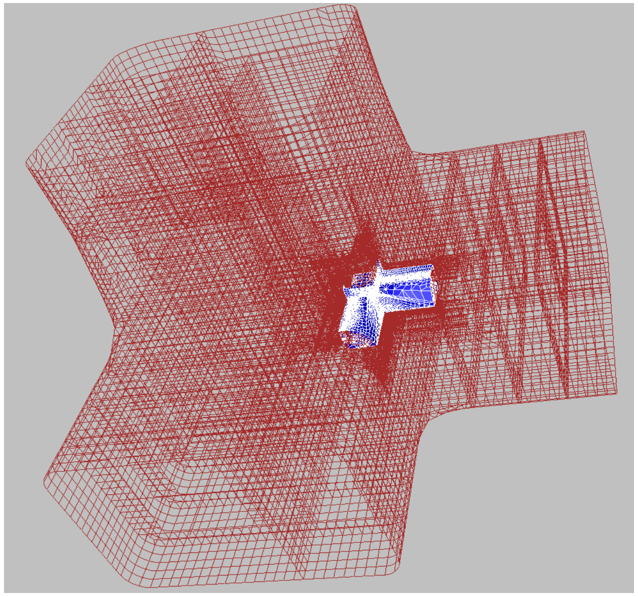




4. Analysis

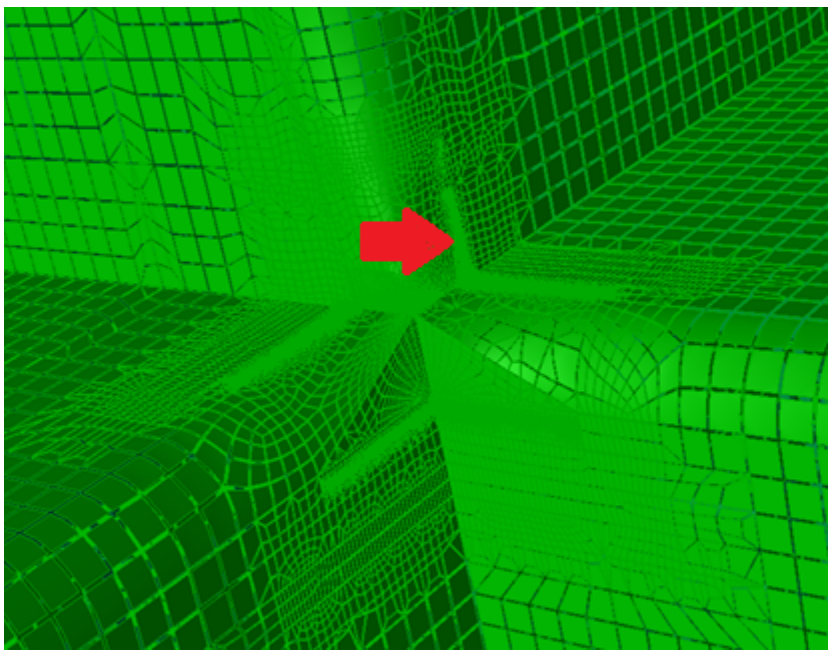
- Critical areas correspond to:
  - Hull and deck connections
  - Column to deck connections
  - Column to pontoon connections
- Considering the most critical area, local model was developed

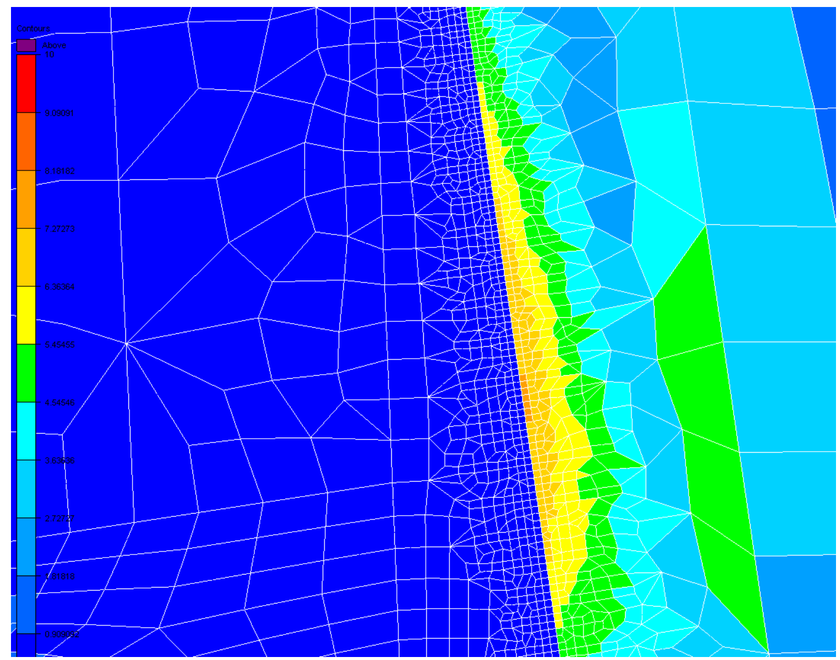




4. Analysis

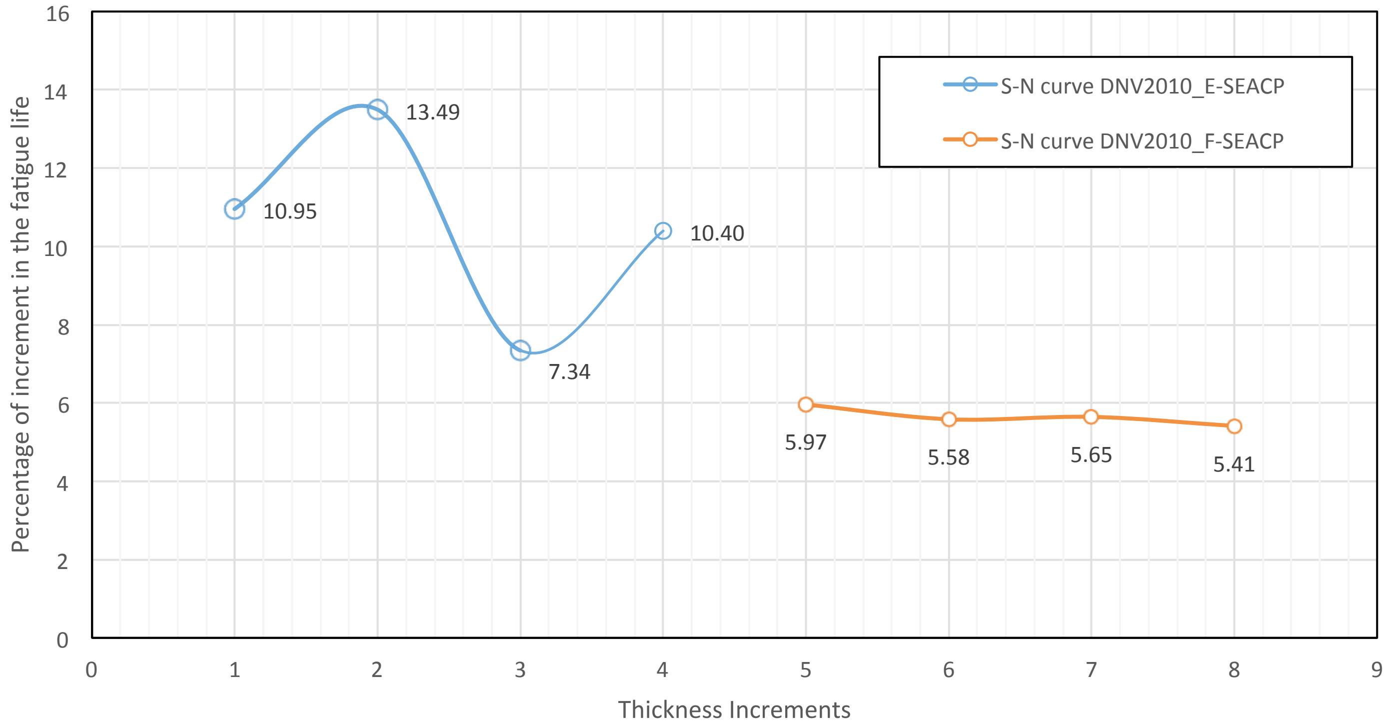
- Identification of possible hot spots in the critical area
- Mesh size t x t
- Effective Notch Stress





5. Results

Increment in the fatigue life for the different thickness of the critical area.



6. Conclusion and Future work

Conclusion

- The increment of thickness could be contemplated as a solution in cases were the TLP design is close to reach the design fatigue life, expecting increments of the 5 % range.

Future work:

- Validation of this results
- Analysis of more TLP structures
- Use of Non-linear models to represent the wave forces
- Performance of a High frequency analysis
- Consideration of further methodologies

Thank for your attention

Adrian Hita