FSI assessment of offshore structures

Martin Eriksson and Björn Ullbrand

2018 Nordic LS-DYNA Users Conference

Company presentation

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Our main areas are within offshore, wind turbines, life science, process engineering, pulp and paper and electronics.

We are situated in the south of Sweden (Staffanstorp outside Malmö) and in the north of Norway (Rognan).

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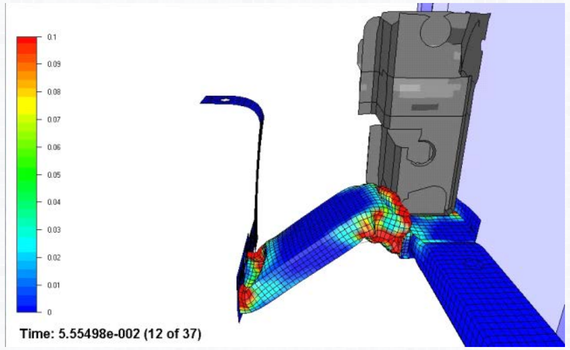
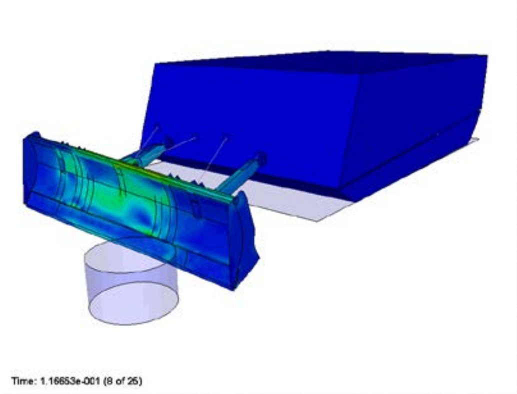
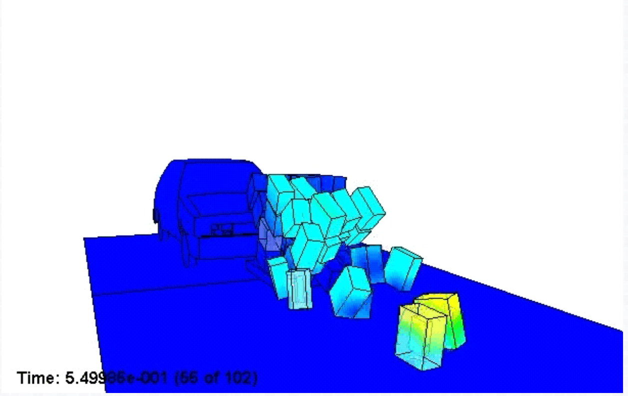
Experience with LS-DYNA

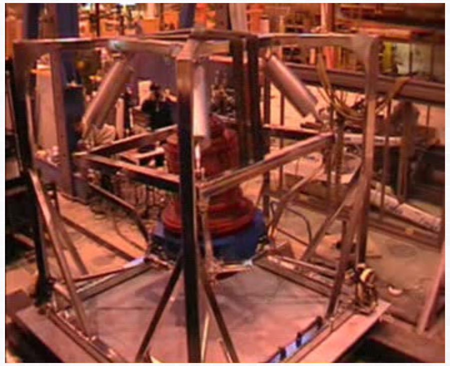
Our competence in and experience with LS-DYNA has been gained from more than 20 years of industrial use in various fields such as:

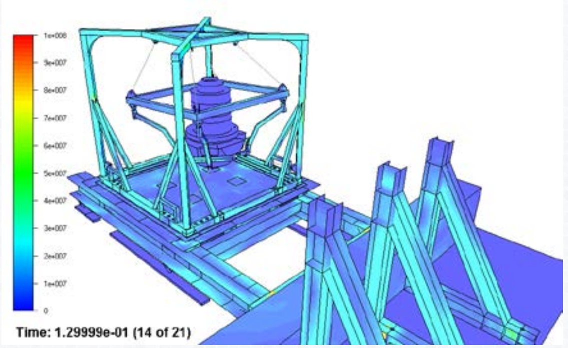
- Automotive
- Cable towing
- Consumer products
- Defense
- Transportation system
- Wheel chairs
- Offshore











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Offshore structures

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Company Certification

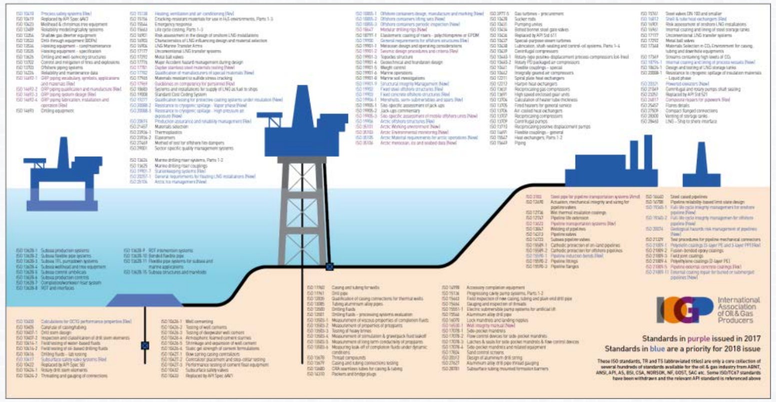
MANAGEMENT SYSTEM CERTIFICATION DNV·GL ISO 9001 ISO 14001 OHSAS 18001

JQS

Regulations

NSOAF North Sea Offshore Authorities Forum

Standards & Recommendations



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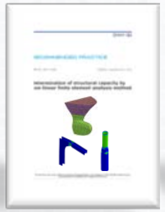

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3rd party verification and classification

DNV·GL

Lloyd's Register

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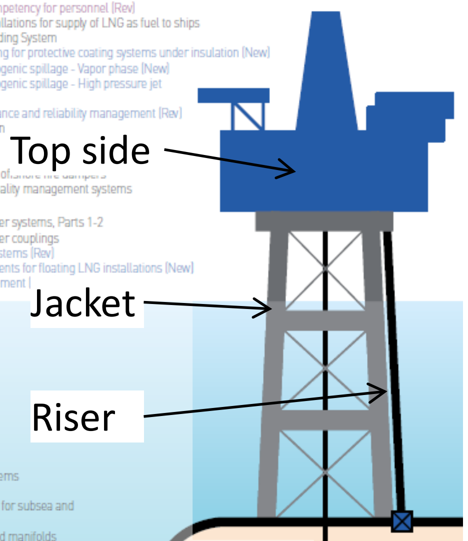
Offshore structures

Fixed platforms:

- Top side weights
  $\leq$ 20 000 Tonnes
- Jacket weights
  $\leq$ 20 000 Tonnes
- Water depths
  $\leq$ 120 Meters



Experience from following scenarios:

- Various installation loads.
- SLS - Service life due to normal use.
- FLS - Fatigue assessment of offshore details using implicit FEA as well as with traditional SCF approach.
- ULS - Assessment of resistance and remaining capacity for extreme loading.
- ALS - Accidental loading due to Ship impact analyses and/or abnormal wind and wave loading with both implicit and explicit FEA.

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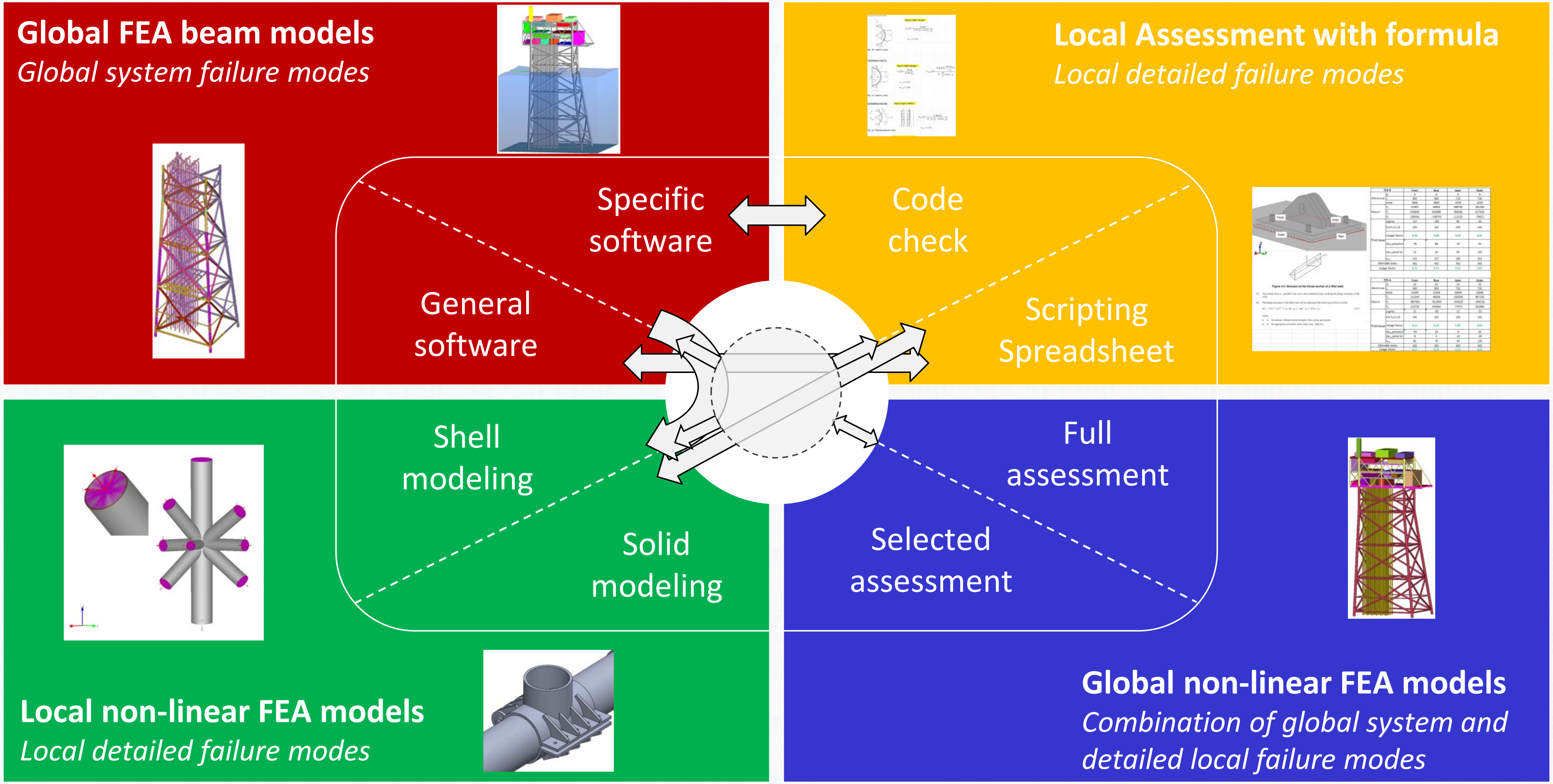
Structural representation



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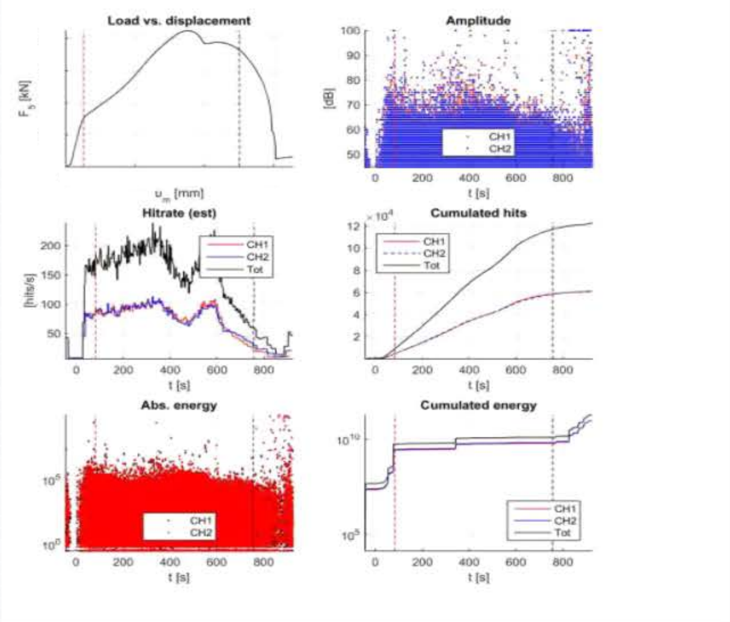
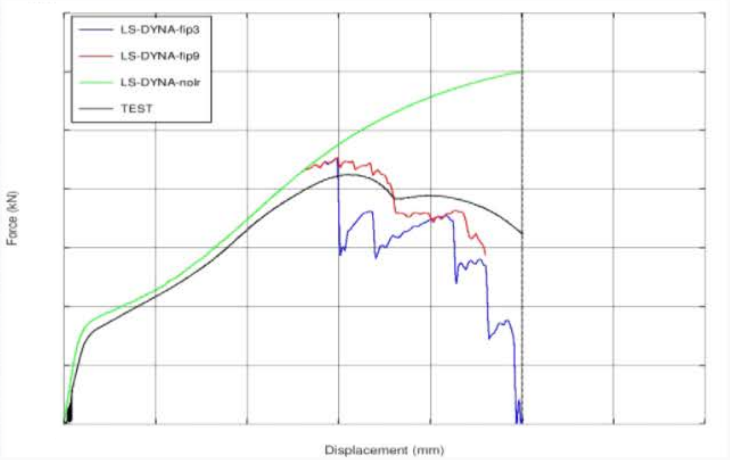
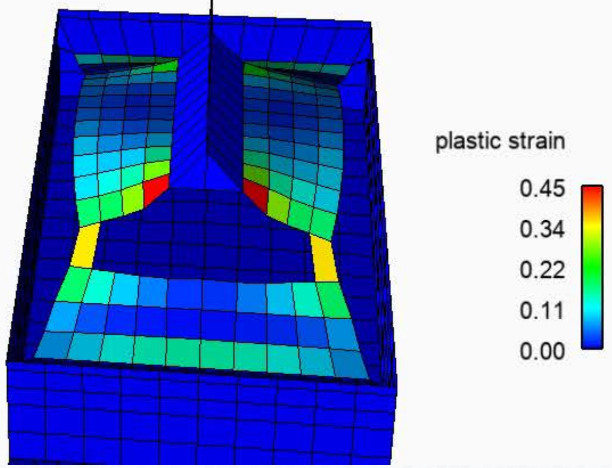
Validation of Structural method







Validated FEA methodology for welded details

- Based on a extensive testing campaign involving
    - *16 test series with various failure mechanisms*
    - *Varying levels of Bending in combination with Tension*
    - *In-plane shear failures*
- Calibration adheres to ISO 19902:2007

Validation includes

- Material
    - *Stress-strain curve*
    - *Failure strain (eroding)*
    - *Number of layers to element failure*
- Shell definition
    - *Element formulation*
    - *Number of through thickness integration points*
- Mesh resolution
    - *Along welds*
    - *Over gaps*
    - *At weld terminations*
- Weld modelling

Failure criteria/limits

- Mean and characteristic strain limits:
    - *Crack initiation / Local necking (degrading fatigue properties)*
    - *Ultimate tensile failure*

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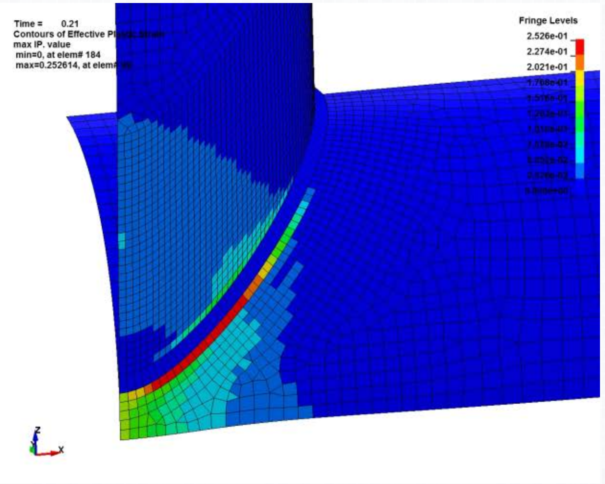
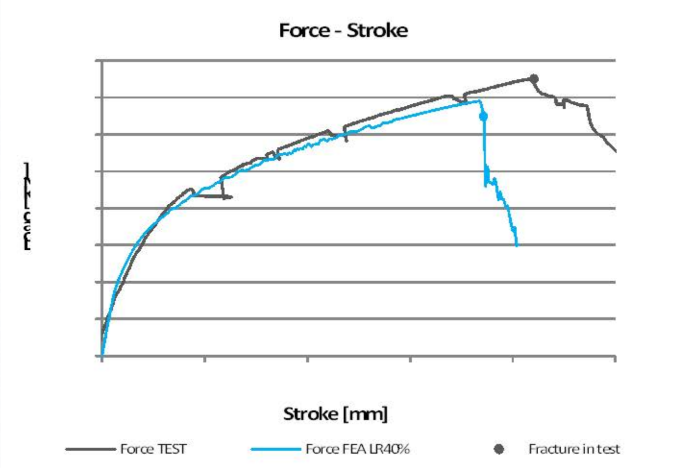
Validation of Structural method





Validated FEA methodology for Tubulars

- Reassessment of previously performed validation
- Confirmation of welded section modelling and failure criteria/limits
- Weld modelling rules for tubular joints
- Cold forming (UOE pipe)

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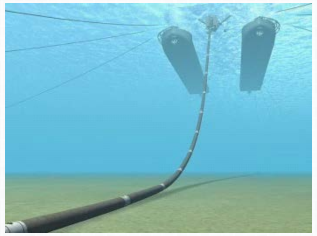
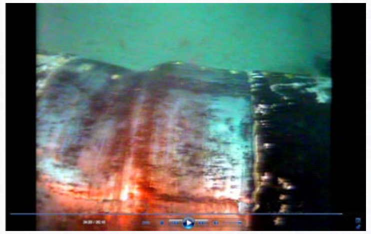
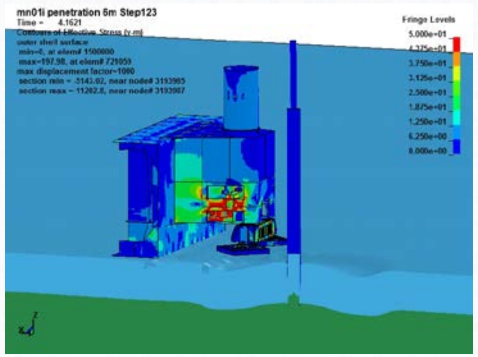
Structural assesment - Offshore structures

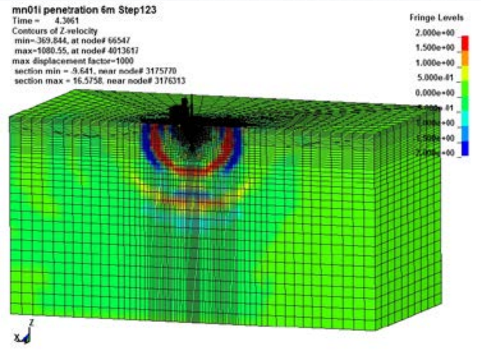
Pipeline installation



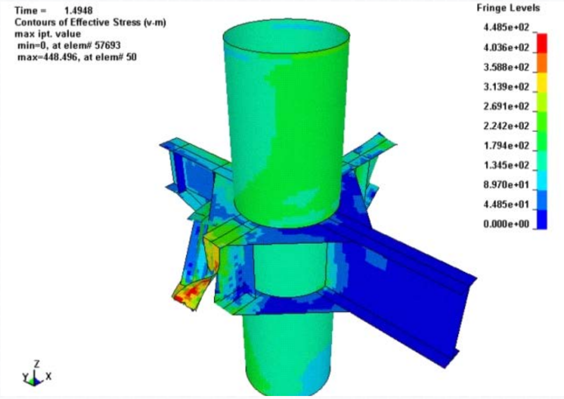


Pile driving – SLS, FLS

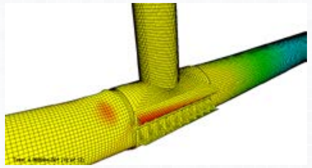


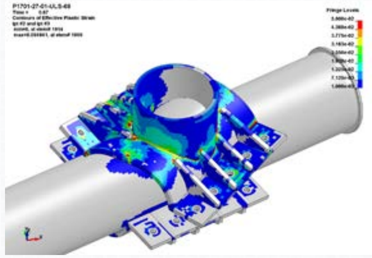


Ultimate capacity – ULS

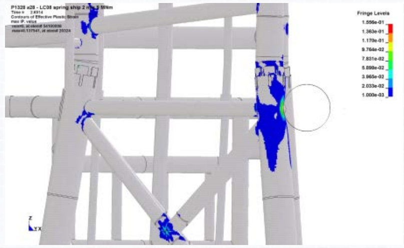


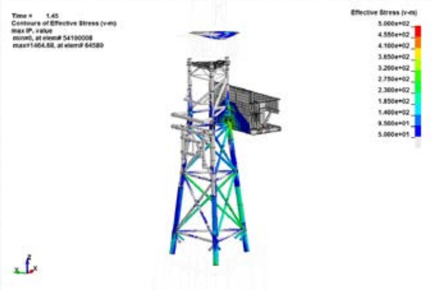
Bolted clamps – ULS, ALS



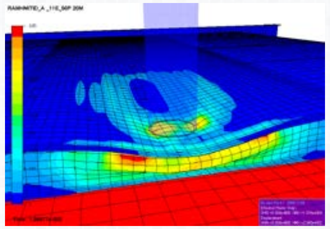


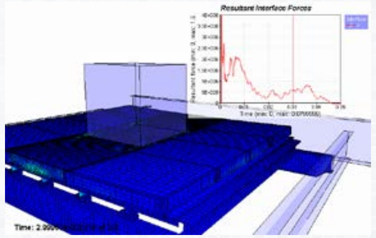
Ship impact – ALS





Dropped objects – ALS





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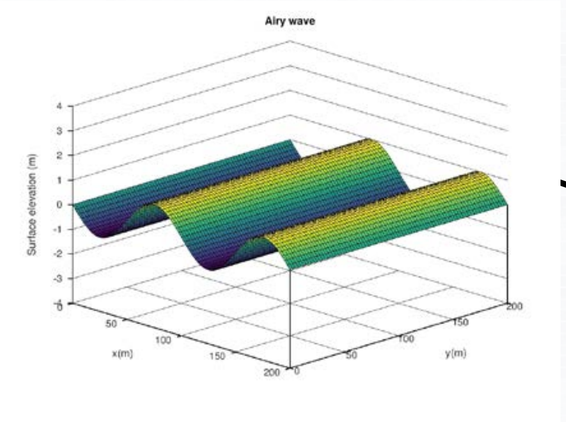
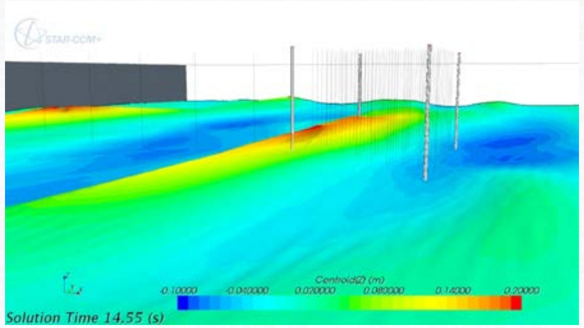
Wave Modeling – Offshore structures

Linear waves



Irregular non-linear waves



Morison equation

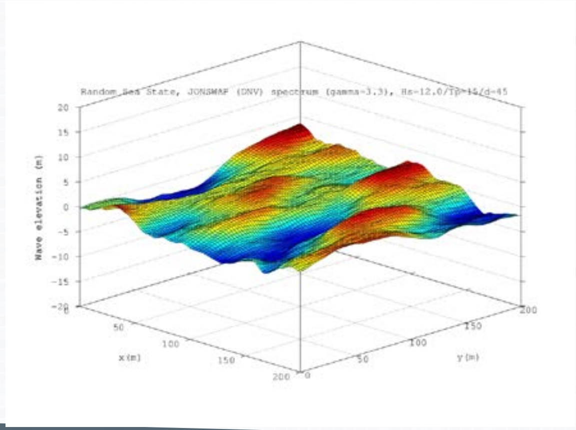
- Force calculated from kinematics
- No direct interaction between fluid and structure

$$F(t) = C_M \rho \frac{\pi}{4} D^2 \dot{u}(t) + C_D \frac{1}{2} \rho D u(t)|u(t)|$$

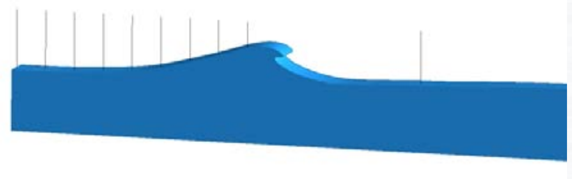
CFD

- Pressure mapped onto structural model
- Interaction between fluid and structure (FSI)

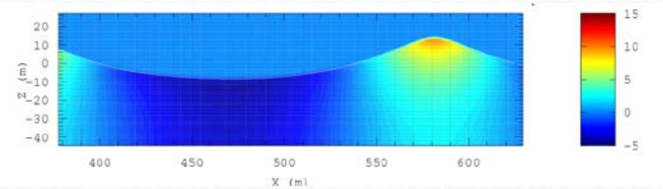
Irregular linear waves



Breaking waves



Stokes 5th order waves



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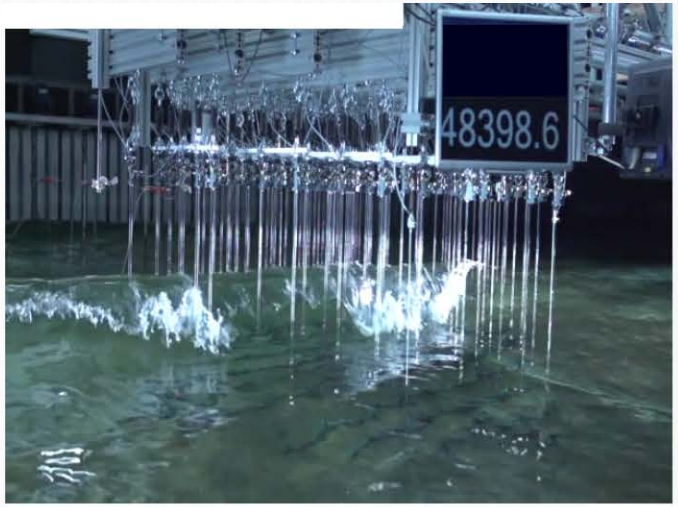
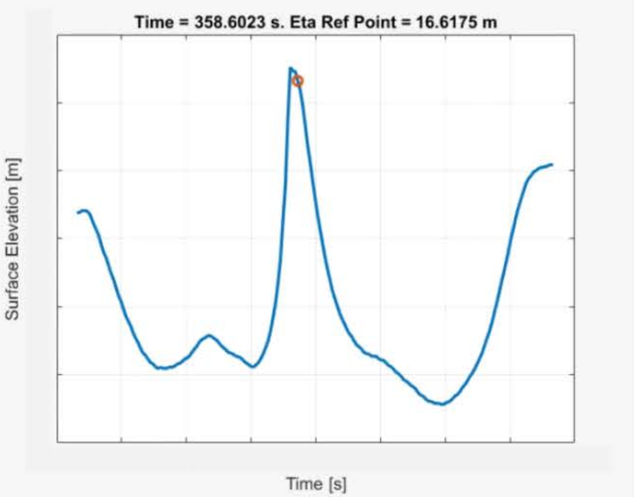
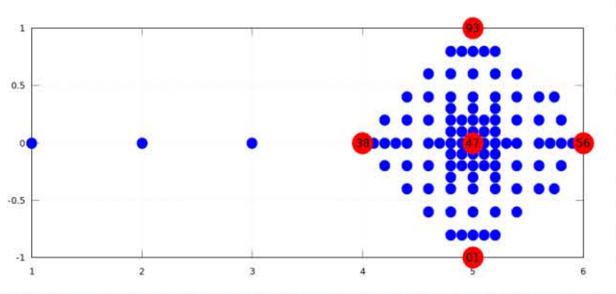
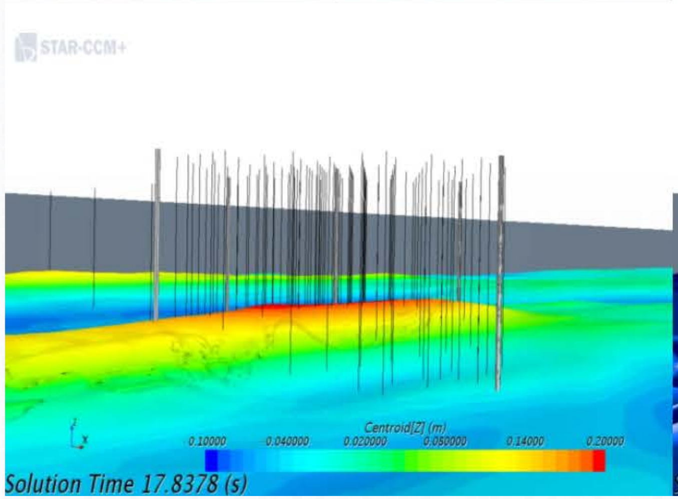
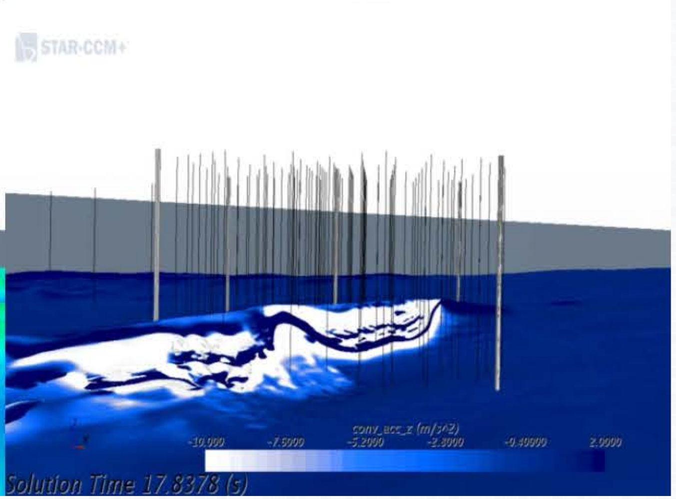
CFD Wave characteristic validation

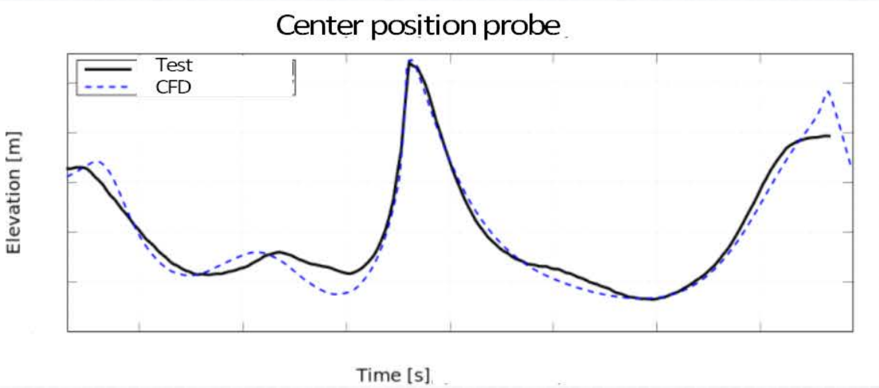












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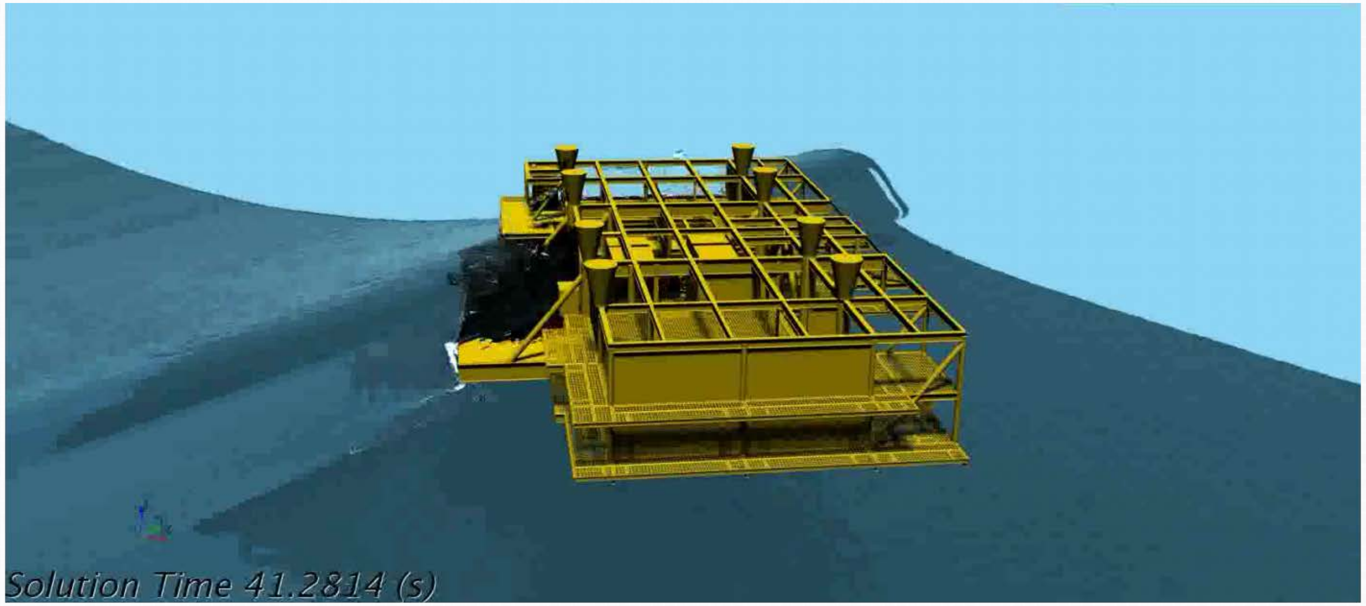
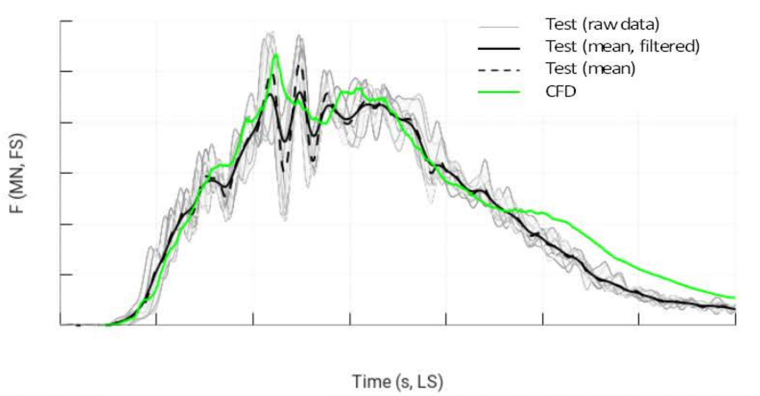
CFD Wave load validation





<u>Validated CFD methodology for Wave loads</u>

- Method
  - *Numerical schemes for discretization and time integration*
  - *Meshing approach and resolution*
  - *Time step optimization*
- Surface elevation
  - *Comparisons with measured wave gauges (2D flume and 3D basins with regular, irregular and breaking waves)*
  - *Comparisons with HD video*
  - *Comparisons with theoretical linear irregular waves (spectrum)*
- Kinematics
  - *Comparisons with PIV and LDA data*
- Loads
  - *Comparisons with measured loads on scale models (regular and breaking waves)*

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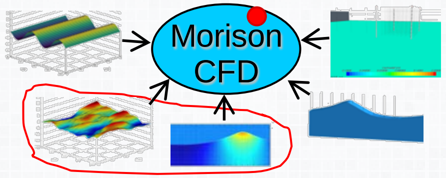
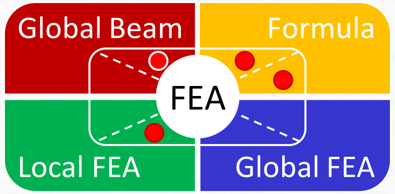
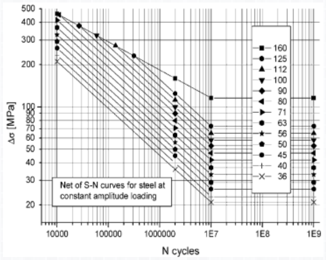
Fatigue evaluation





Project description:
Fatigue (FLS) evaluation by e.g. Influence Factor (IFs) approach.
Extrapolation of stress according to e.g. IIW and DNV RP-C203.

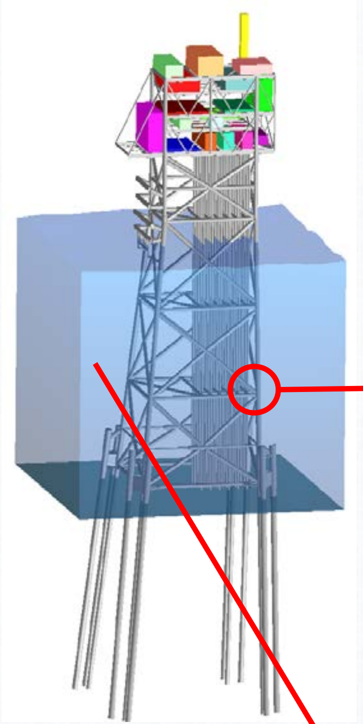
SN-curves



Global Beam-model

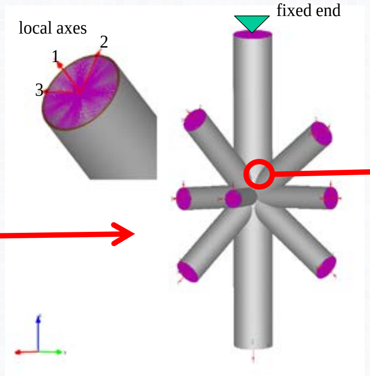
Sea level

Seabed



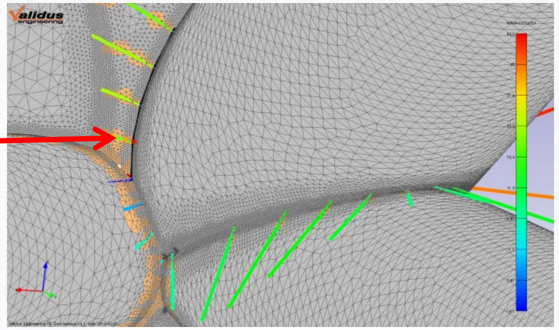
Local FE-model (IF-model)

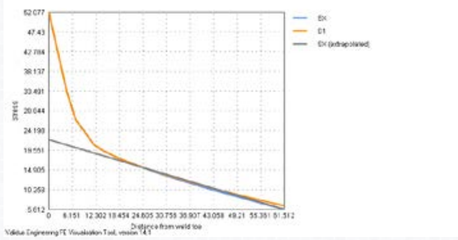
Model extent



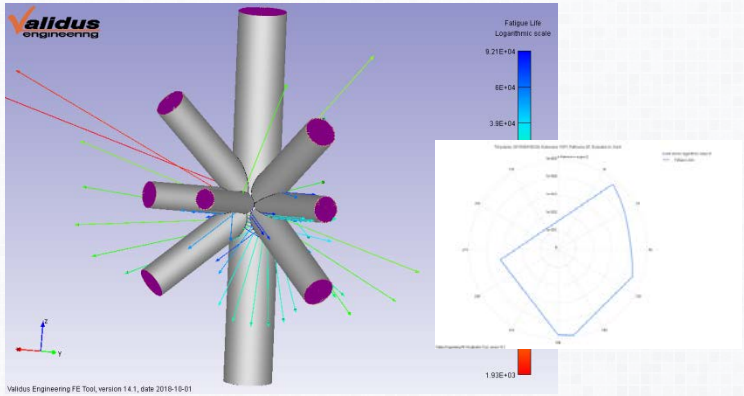
All Tubular intersection welds evaluated

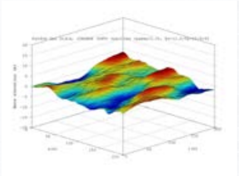
Weld toes – Stress range extraction





Fatigue life





Load histories for several sea states

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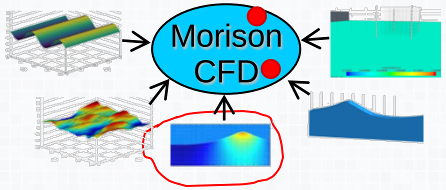
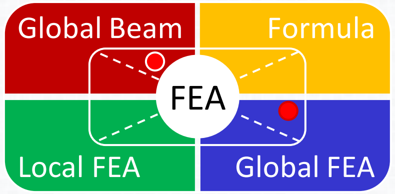




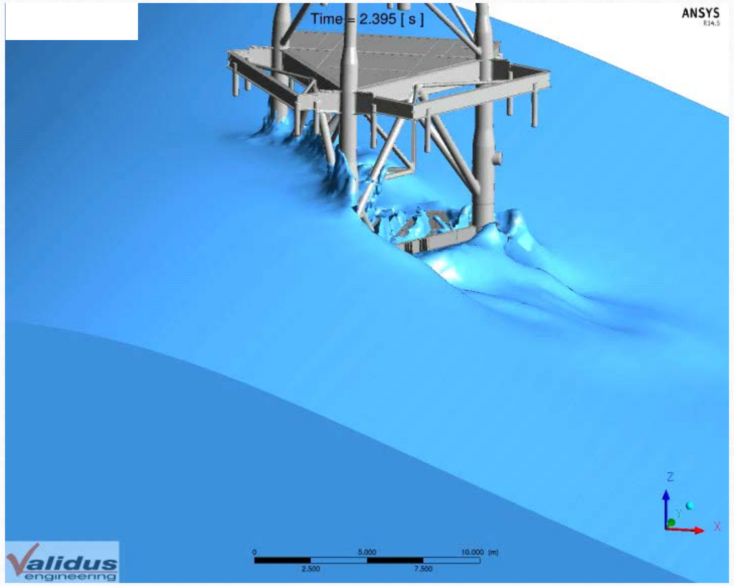
Wave in deck evaluation

Project description:
Assessment of structural integrity of complete platform due to extreme wave in deck loading (ULS).

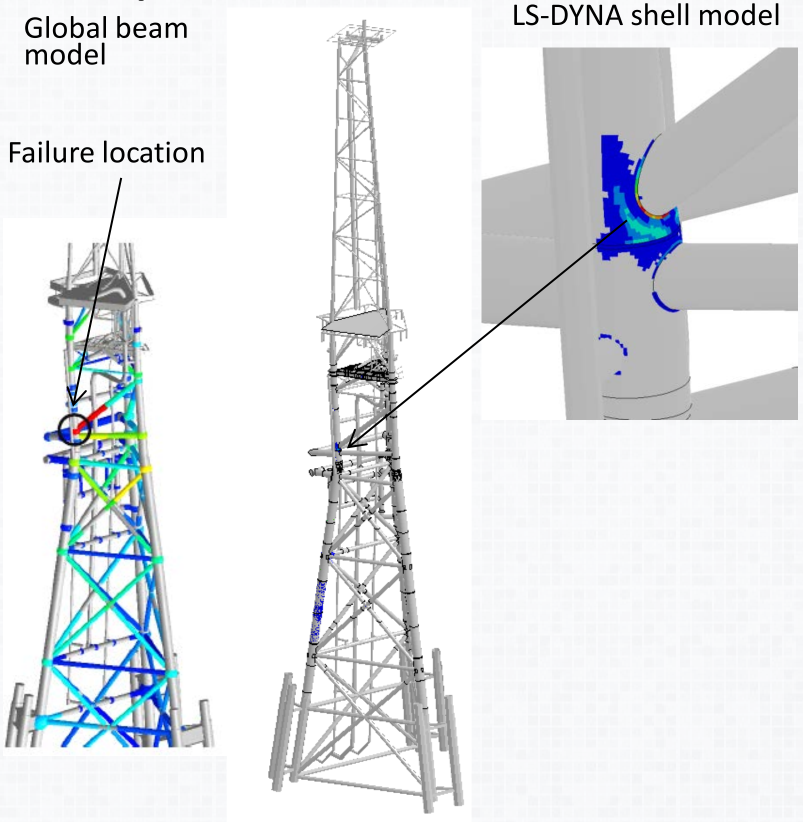
Loading:

- Steady state wind load
- Stokes 5th order wave
- Detailed 1-way FSI analysis that fails in the global beam analysis.

- Repeated wave loading should also be evaluated (90% wave height for 2nd wave according to standards).



1st wave peak results



- Problem areas seen in LS-DYNA analysis agrees with observations in the global analysis.
- Overall structural integrity is obtained.

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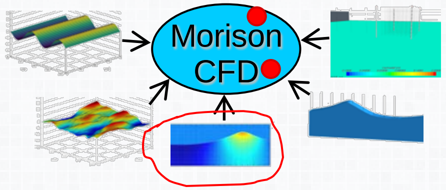
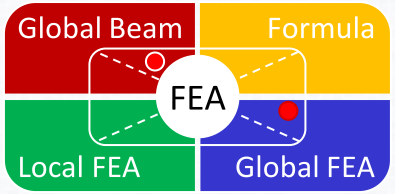
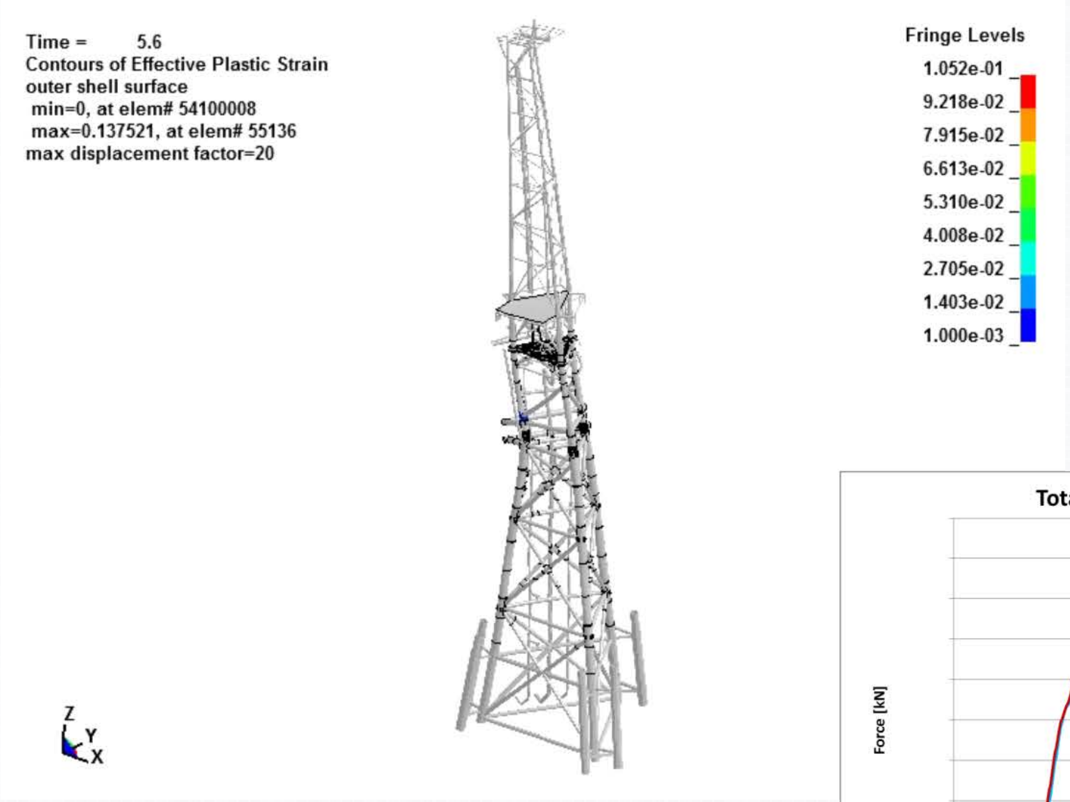
Wave in deck evaluation

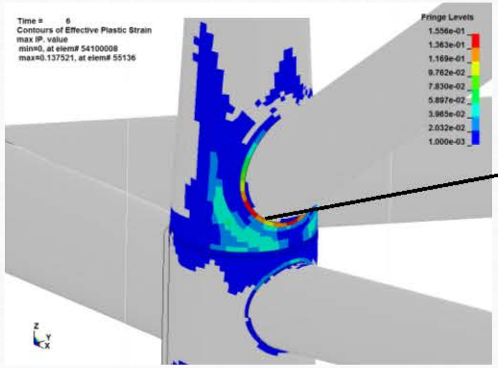


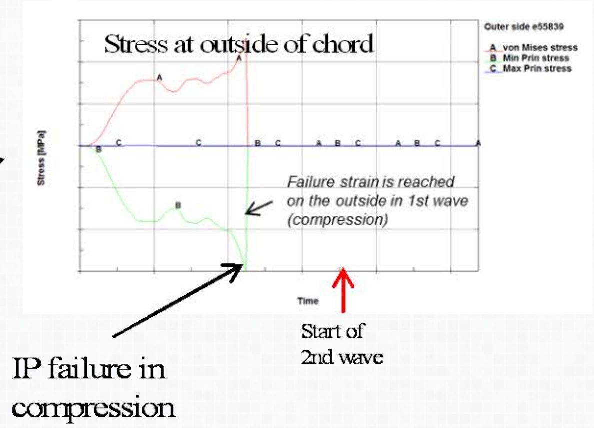


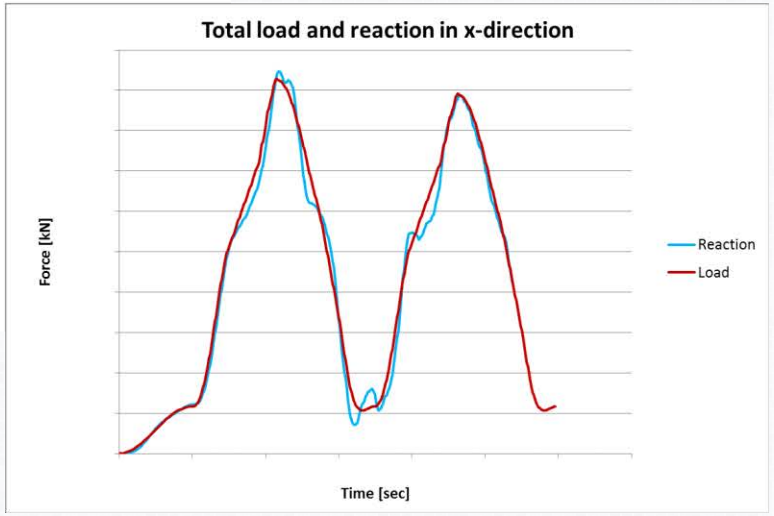
Assessment of two subsequent wave loads



Displacement scale factor = 20







General conclusions:

Overall structural integrity is obtained.

However local failure develops in compressions.

The yield surface grows during 1st wave loading, unloading and 2nd wave.

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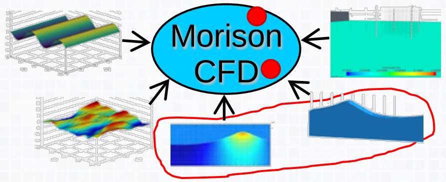
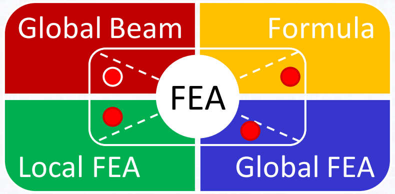
Wave in Bridge evaluation





Project description:

Bridges structure reinforced to comply with an Accidental Limit State (ALS), i.e. the bridge must be able to survive the 10’000 year Wave in Bridge scenario without total collapse.

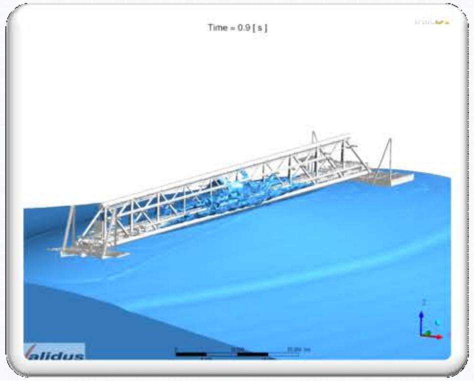
Design iterations
Updated reinforcements design based on results.

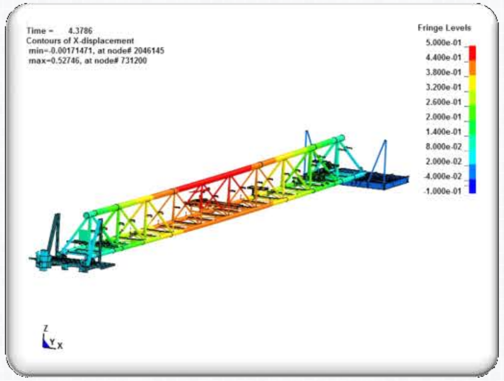
As built design
Bridge according to as built information

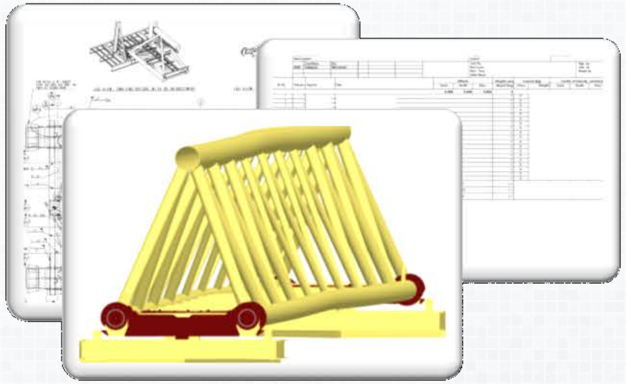
→ **Wave loading**
Wind and Stokes 5th order waves and Breaking waves

→ **Structural assessment**
structural model including beams, shells and solids

→ **Result**
Reinforcement drawings, Weight reporting, design reports







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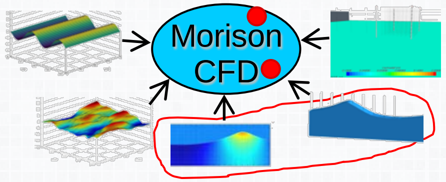
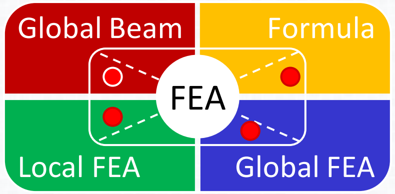
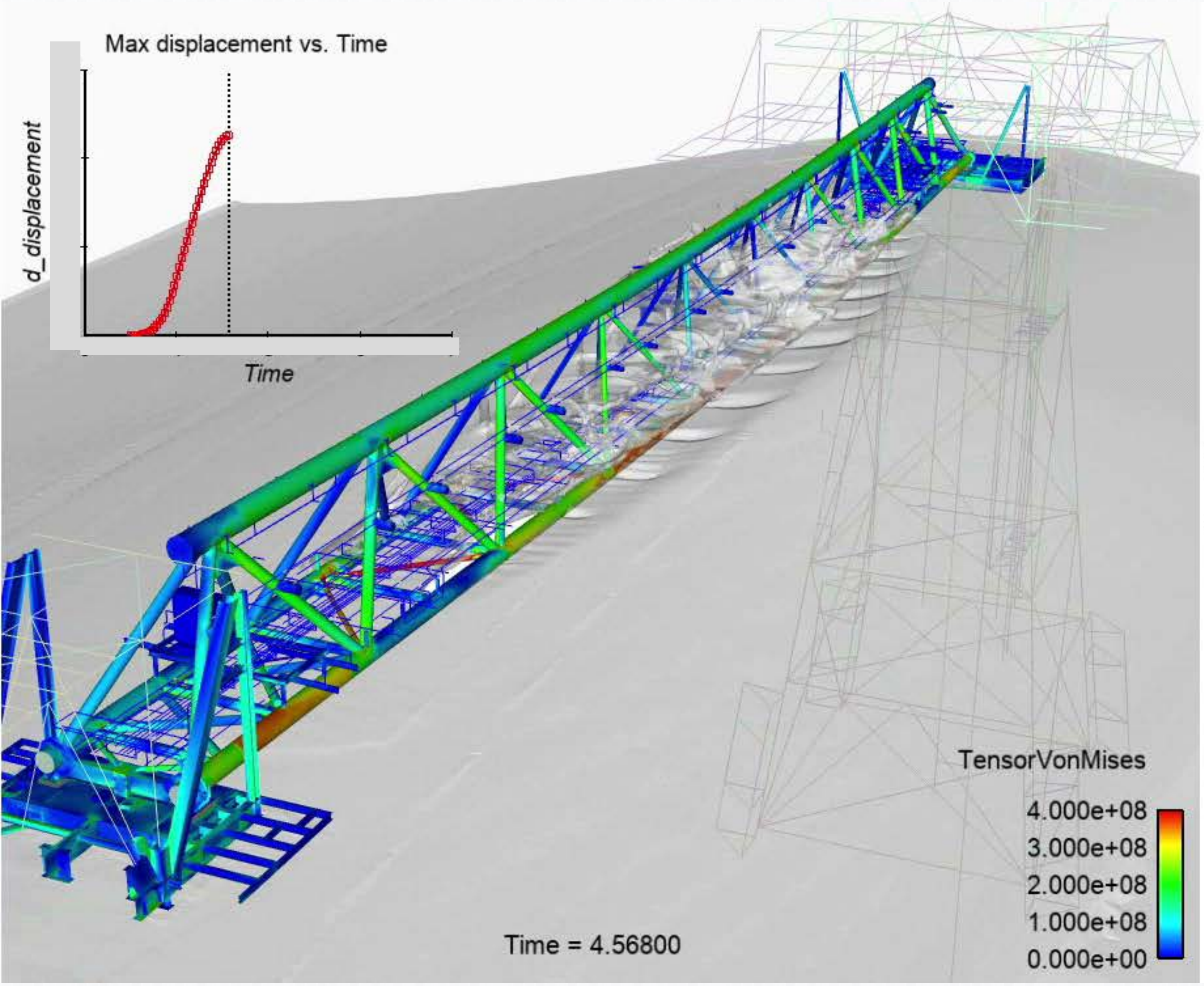
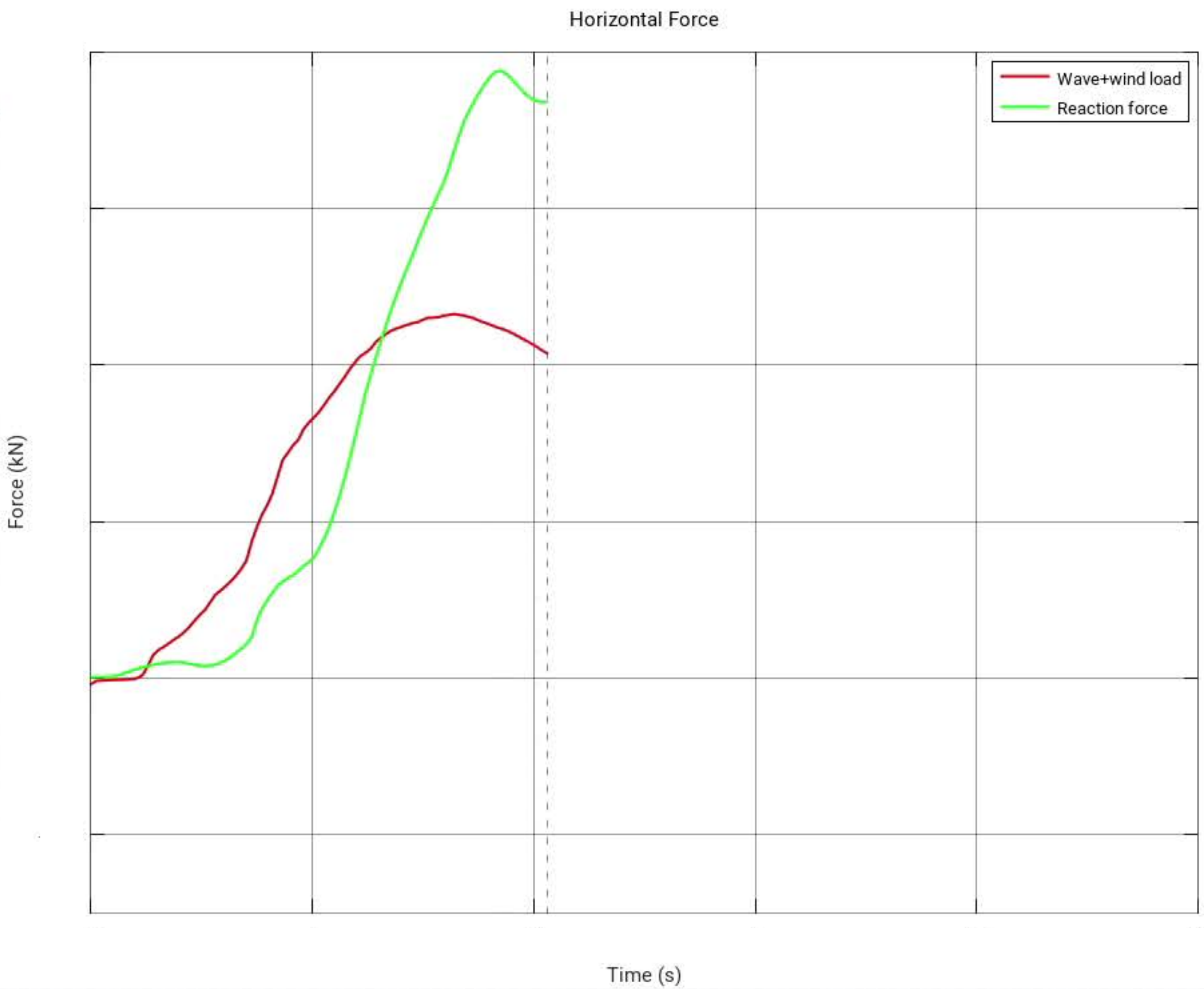
Wave in Bridge evaluation









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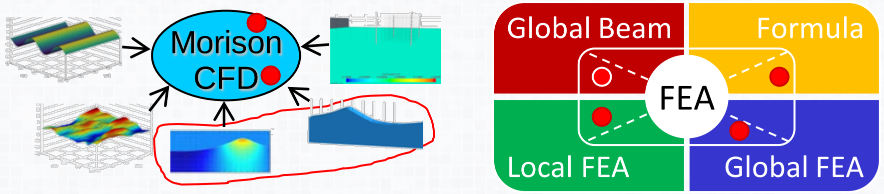
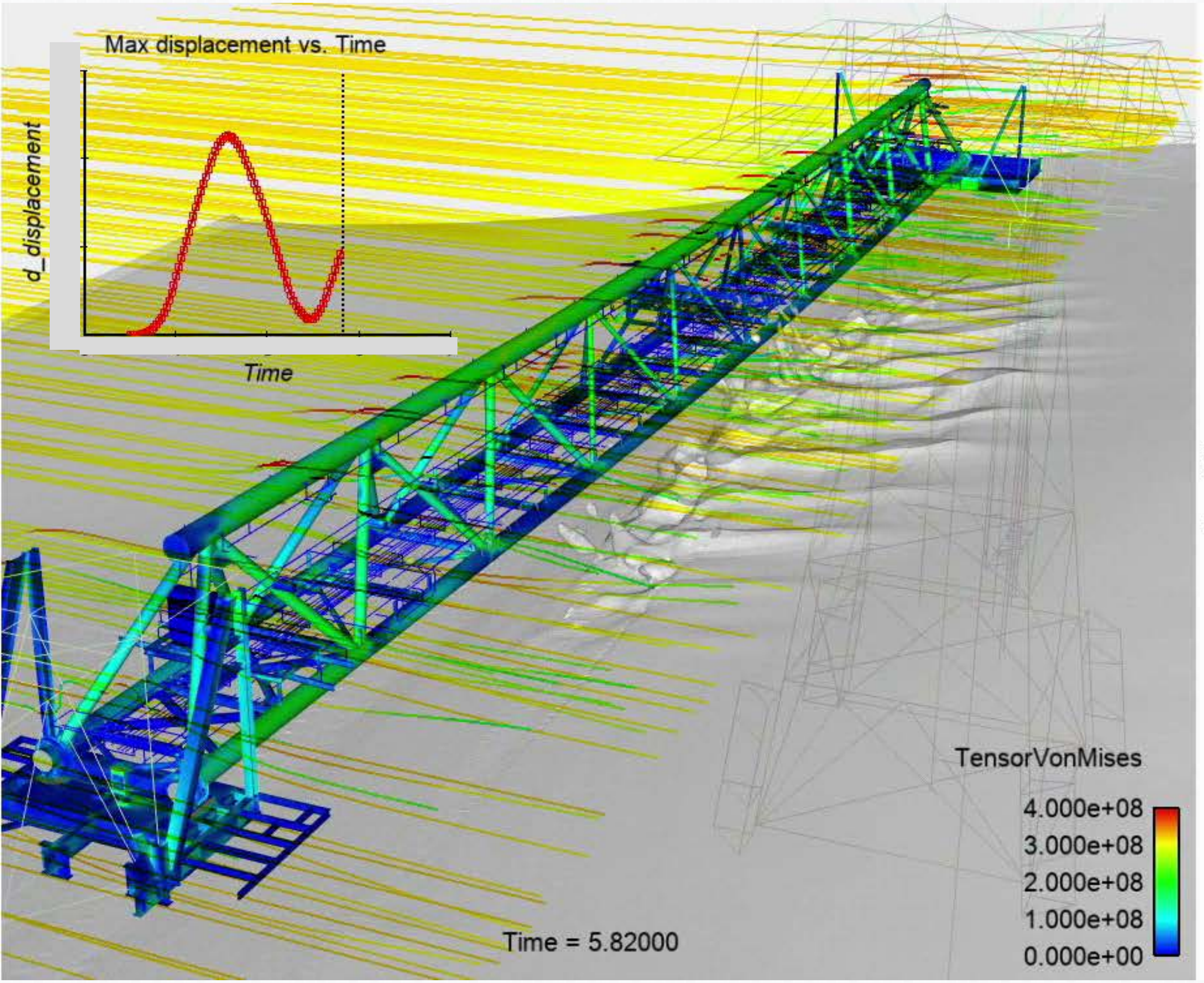
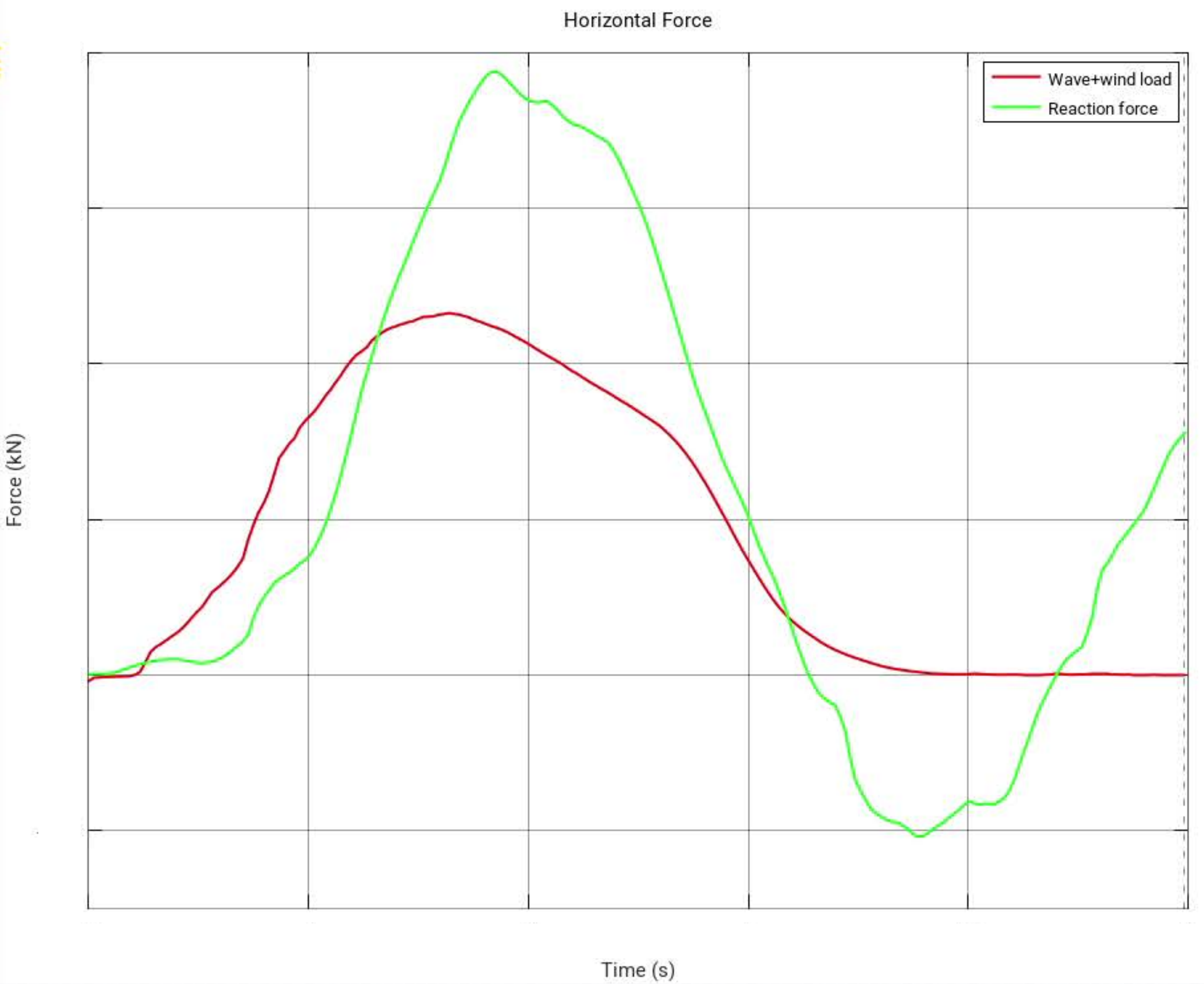
Wave in Bridge evaluation







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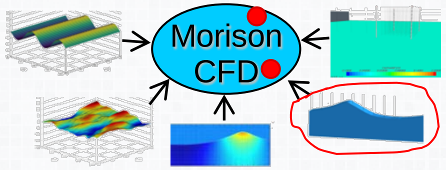
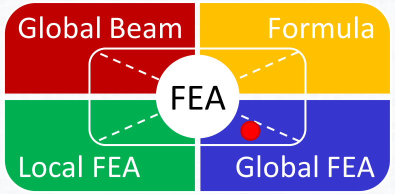
Wave in Riser evaluation

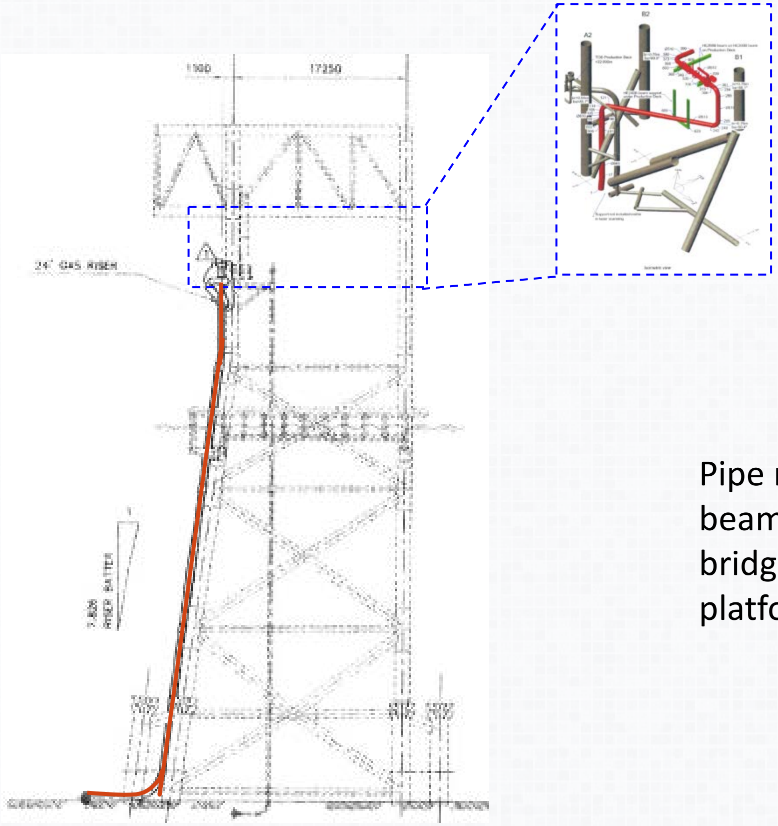




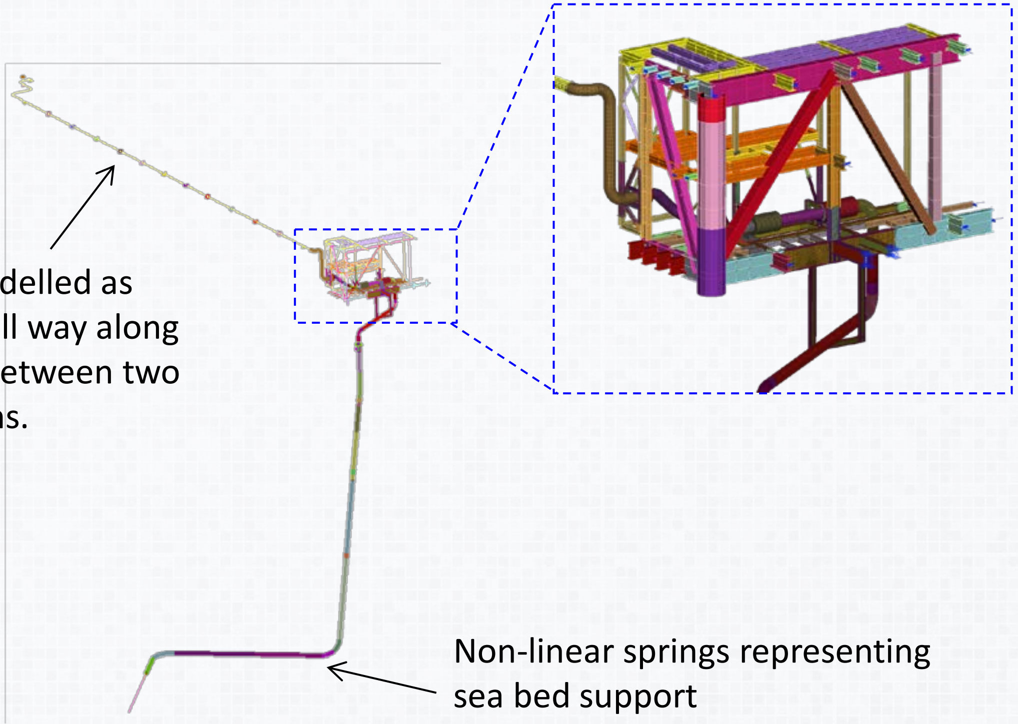
Project description:
Assessment of structural integrity of risers due to Abnormal breaking (ALS) waves

Loading:

- Gravity
- 12 MPa internal pressure
- Hydro static pressure
- Wave loading with kinematics extracted from 3D CFD analyses
- Morison equation applied on structural elements



Top side structure and Riser modeled with shell elements



Pipe modelled as beams all way along bridge between two platforms.

Non-linear springs representing sea bed support

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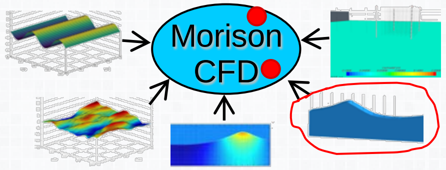
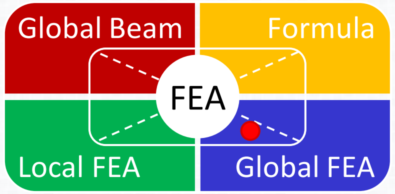
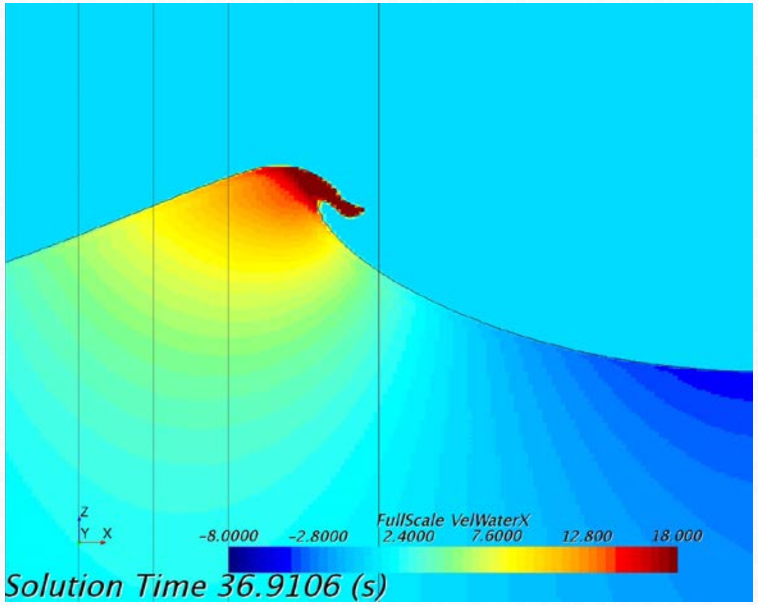
Wave in Riser evaluation

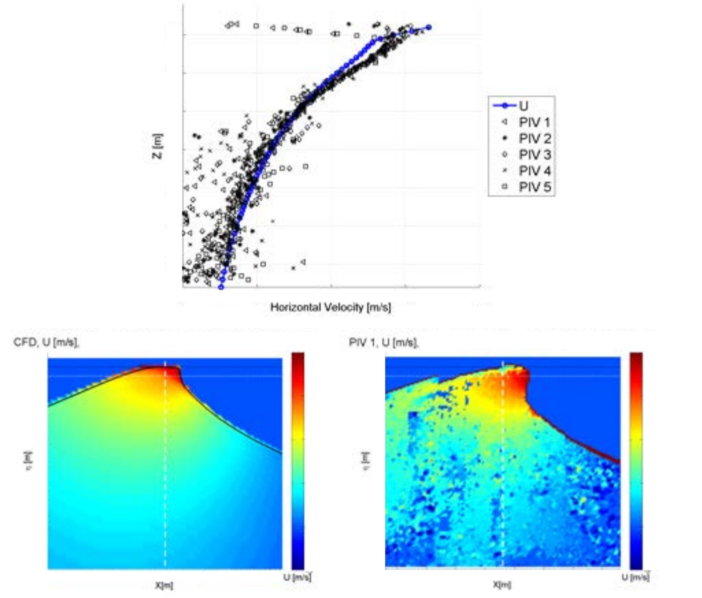




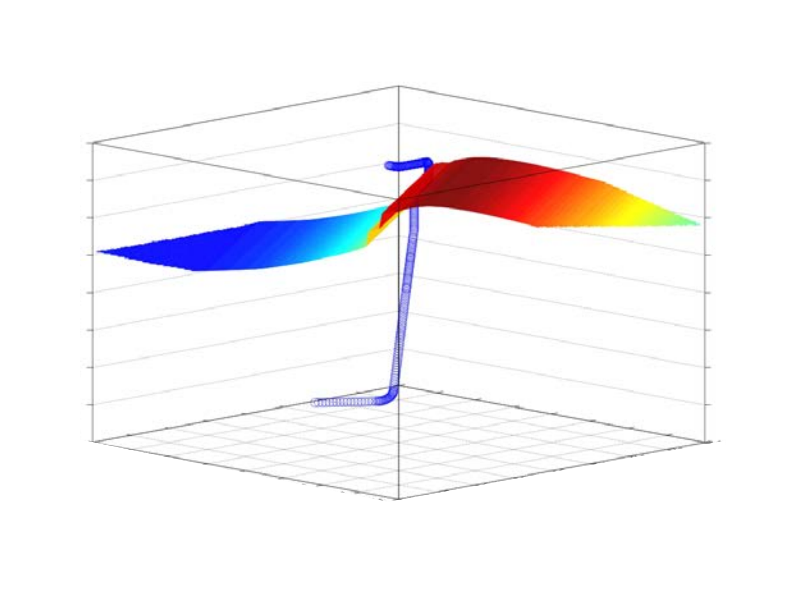
Wave load generation



CFD analysis of breaking wave providing kinematics (velocity and acceleration fields) as input to subsequent Morison analyses.



Validation of CFD results using PIV.



Octave script for generating loads on LS-DYNA riser model based on Morison equation using kinematics from CFD analysis without structure.

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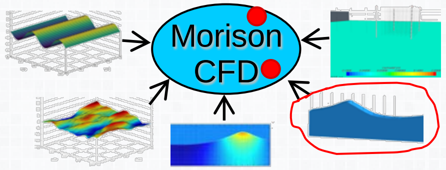
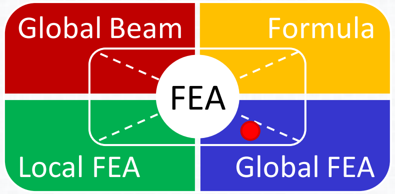
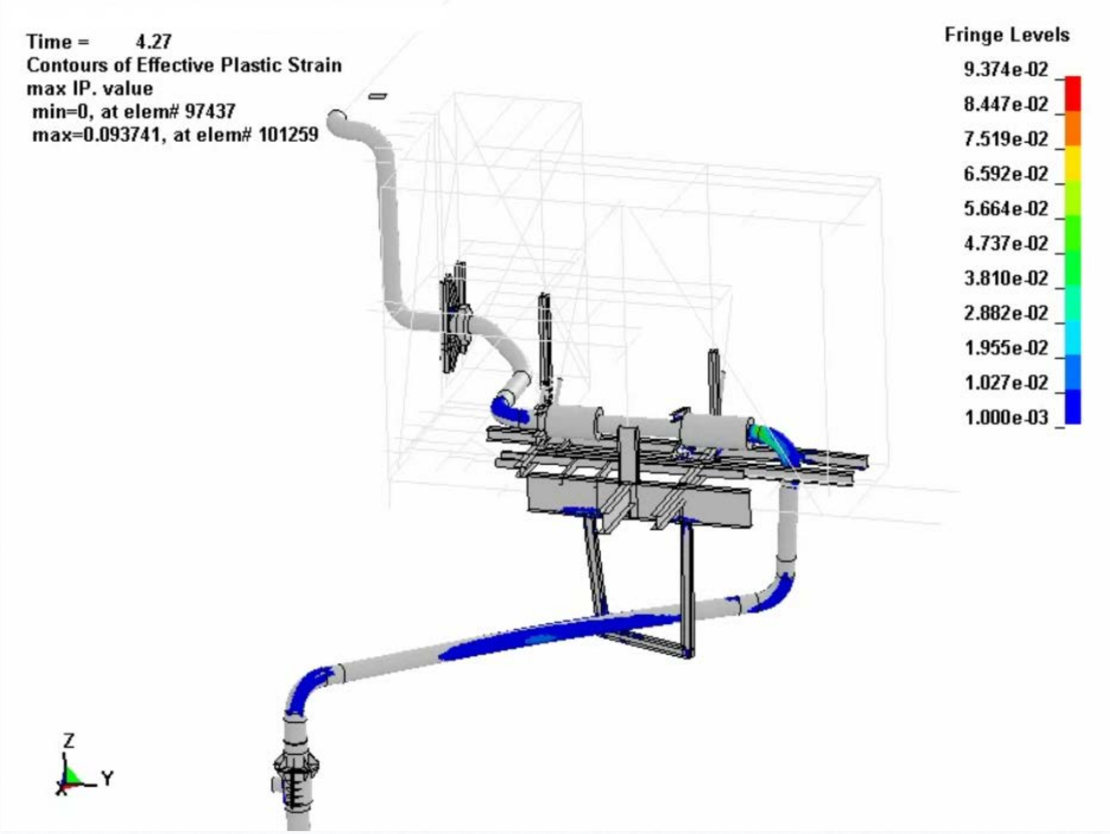
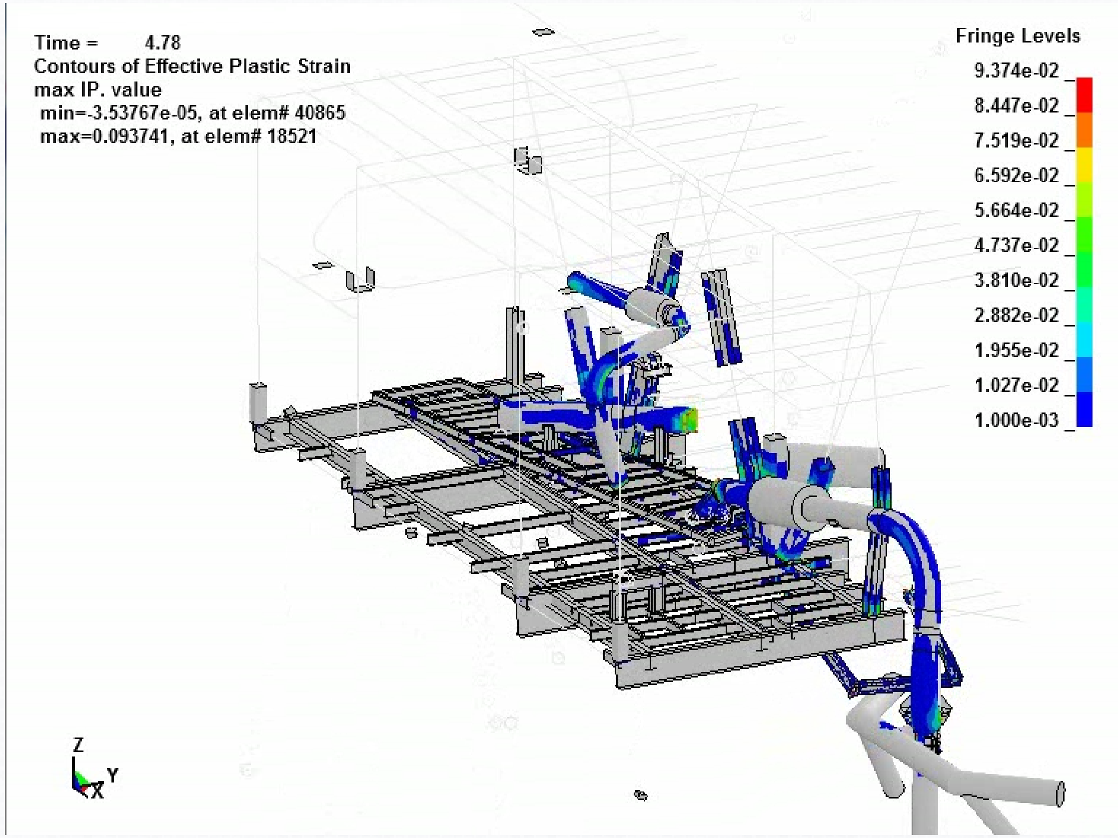
Wave in Riser evaluation





Structural response





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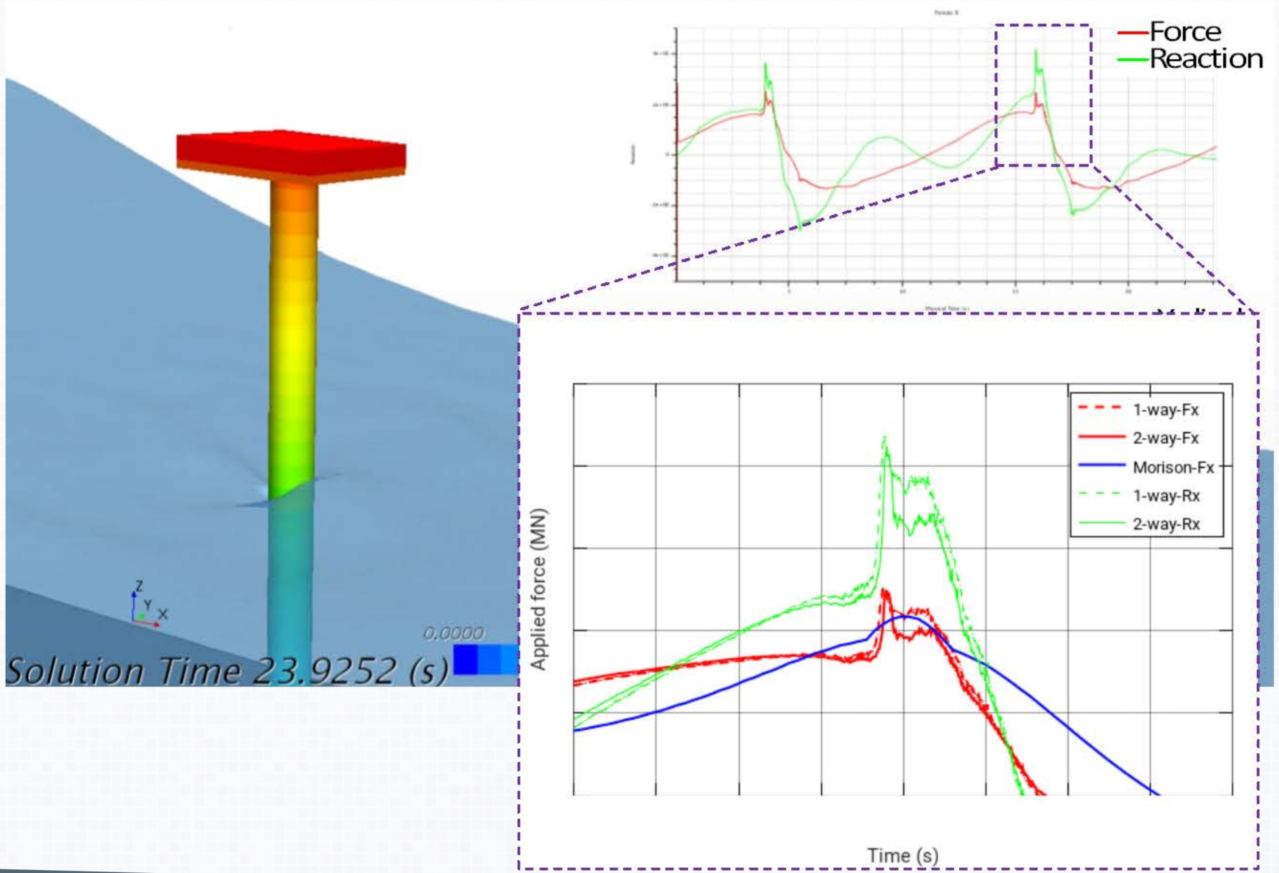
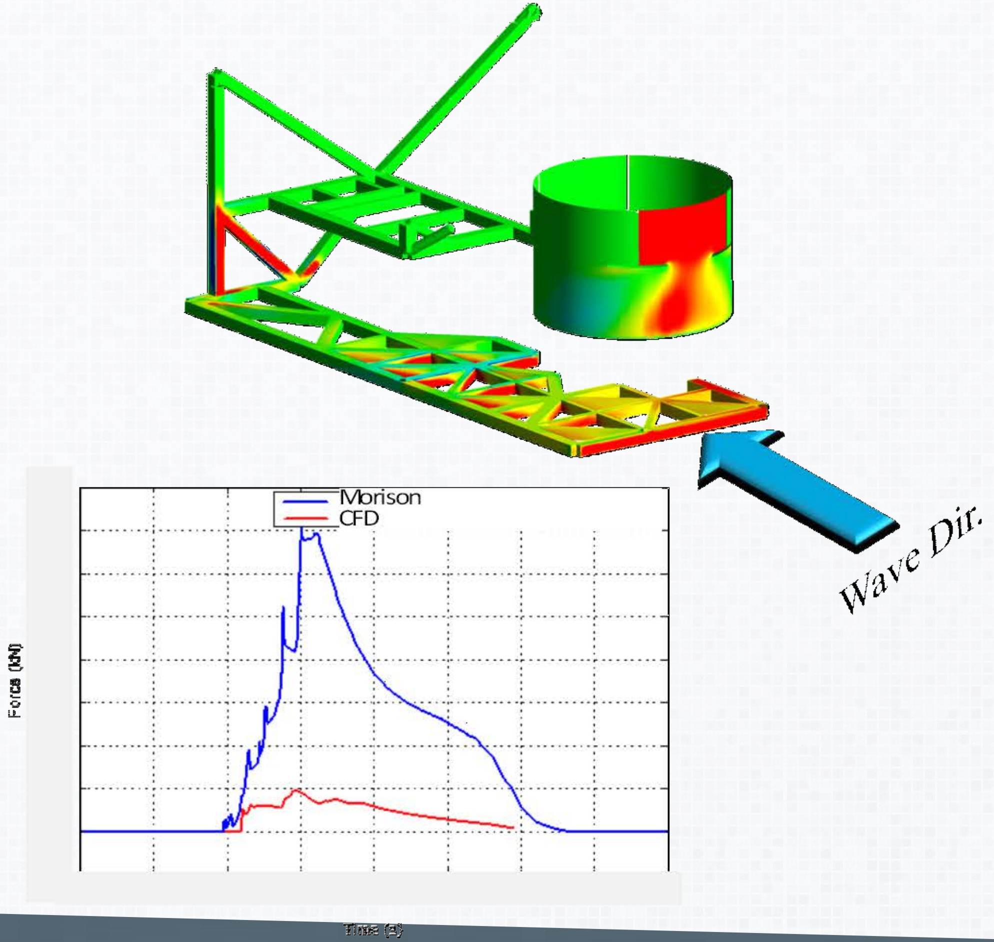
Future challenges – Loading

Increased accuracy on loading through:
2-way FSI

Adapted loading: Morison, SPH …





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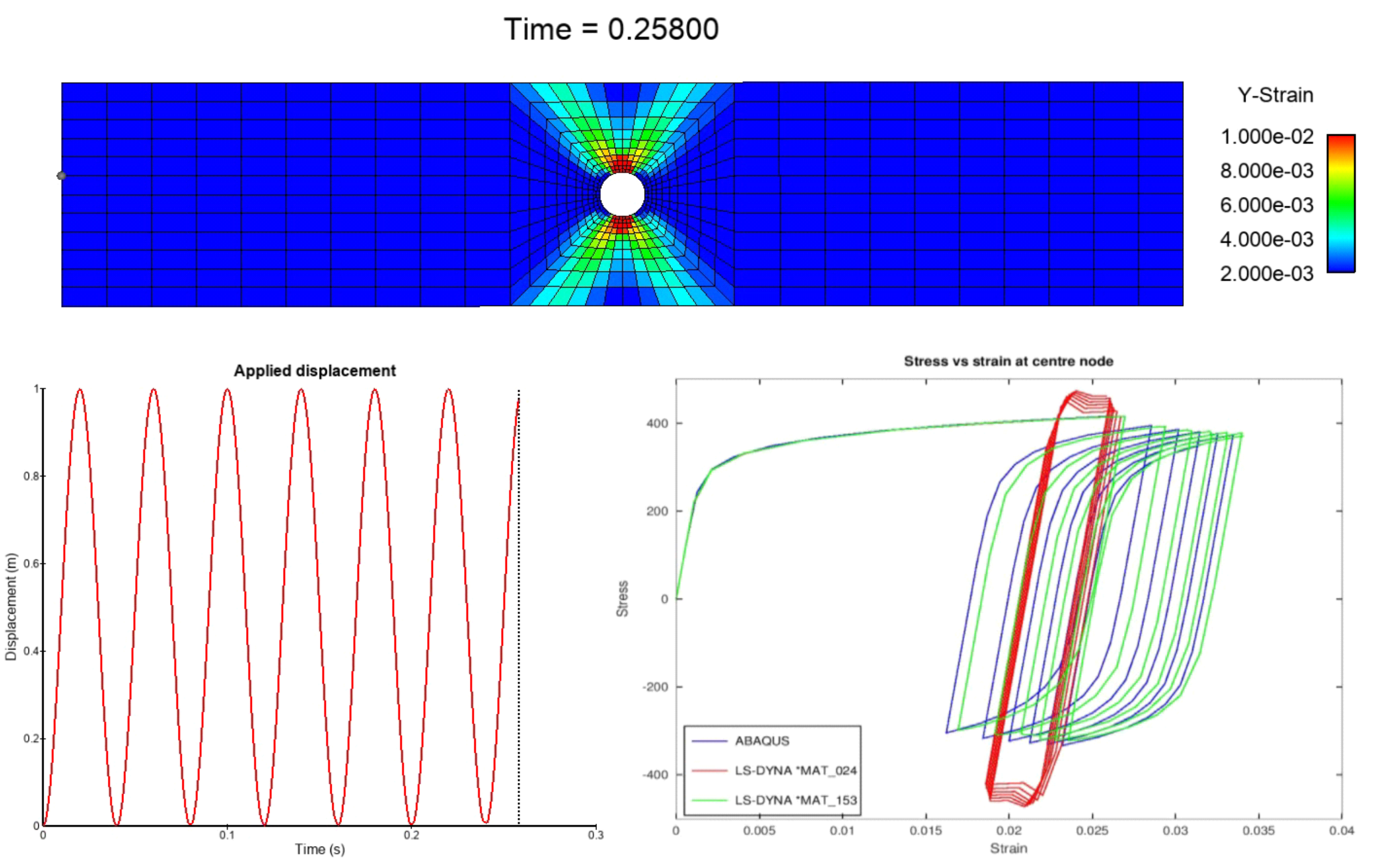
Future challenges – Material & Execution

Improved structural response evaluation due to cyclic loading

- Use Non-linear kinematic hardening such as the Chaboche material model*.
- Further utilization of automatic shift between implicit and explicit solver scheme to allow for assessment of Irregular non-linear waves.



Example 8.10 from DNV-GL_RP-C208

* Implementation into LS-DYNA R11.0.0 made available by DYNAmore Nordic.

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Thank you for your attention

Breaking wave on a monopile offshore platform in shallow water (© www.flyingfocus.nl)

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Validus Engineering AB, Staffanstorp
Postal Adress: P.O. Box 806 SE-245 18 Staffanstorp Sweden
Phone: +46 46 26 10 200
Fax: +46 46 26 10 290
Visiting Address: Valhallavägen 41 245 32 Staffanstorp
E-mail: info@valeng.com
WWW: https://www.valeng.com/

Map

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