Quasi-dynamic global strength analysis of a passenger ship in regular waves

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Introduction

Aims

- Prepare the procedure and conduct global strength analysis for a typical cruise ship
- Implement quasi-dynamic analysis for global strength
- Compare class society's wave bending moment with the results

Limitations

- Conceptual early design level
- Attention to the hydrodynamic loading
- Simplified seakeeping analysis, for regular waves only

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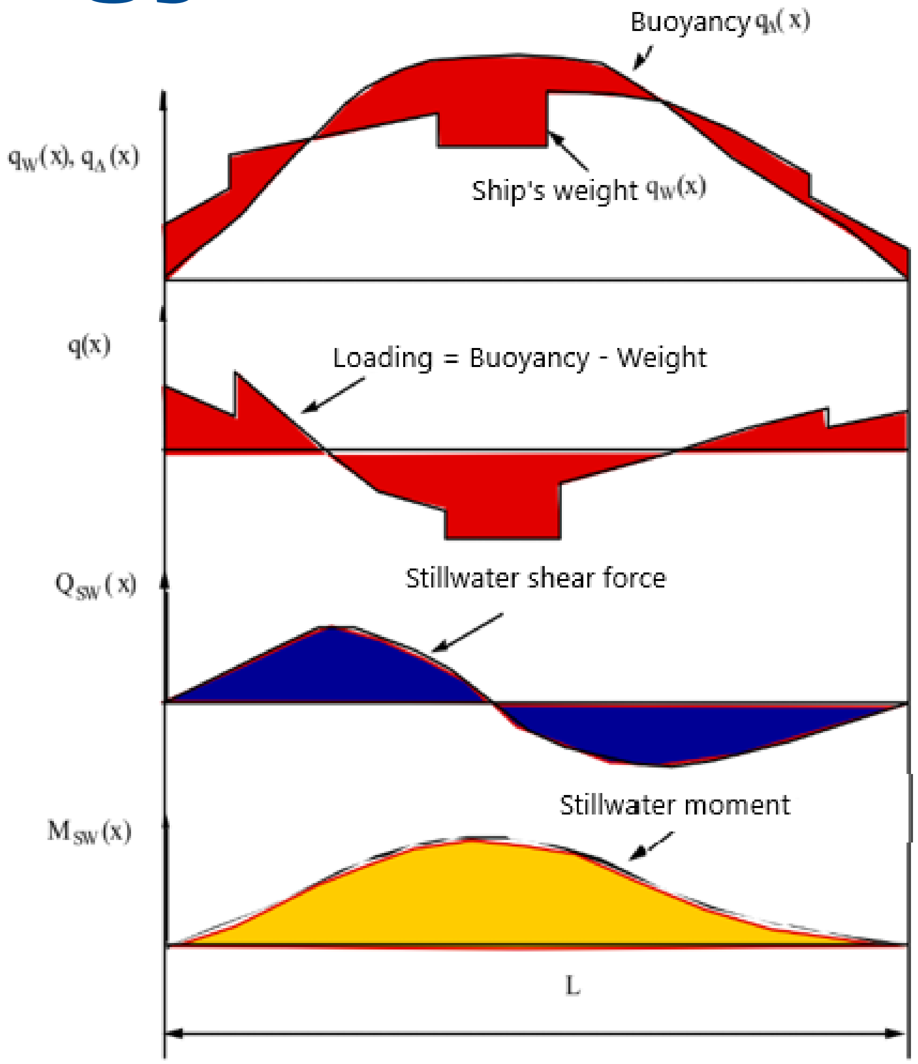
Methodology

1. **Still water condition**
    - Ship's weight
    - Buoyancy force = hydrostatic pressure

This results in:

- Still water bending moment
- Still water shear force



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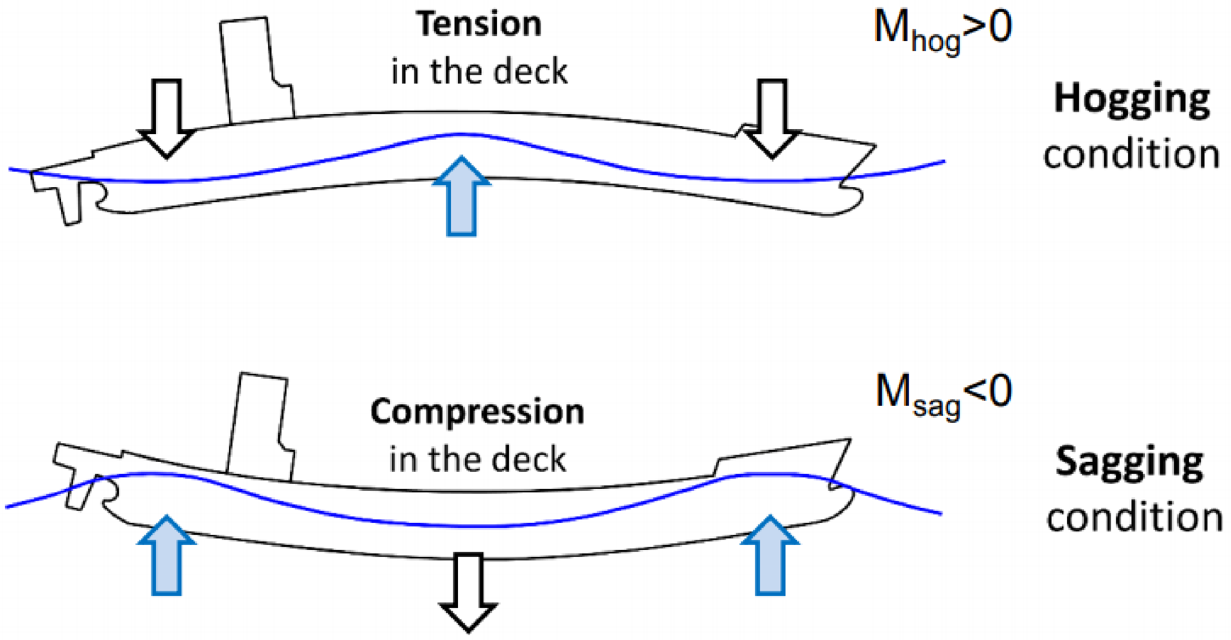
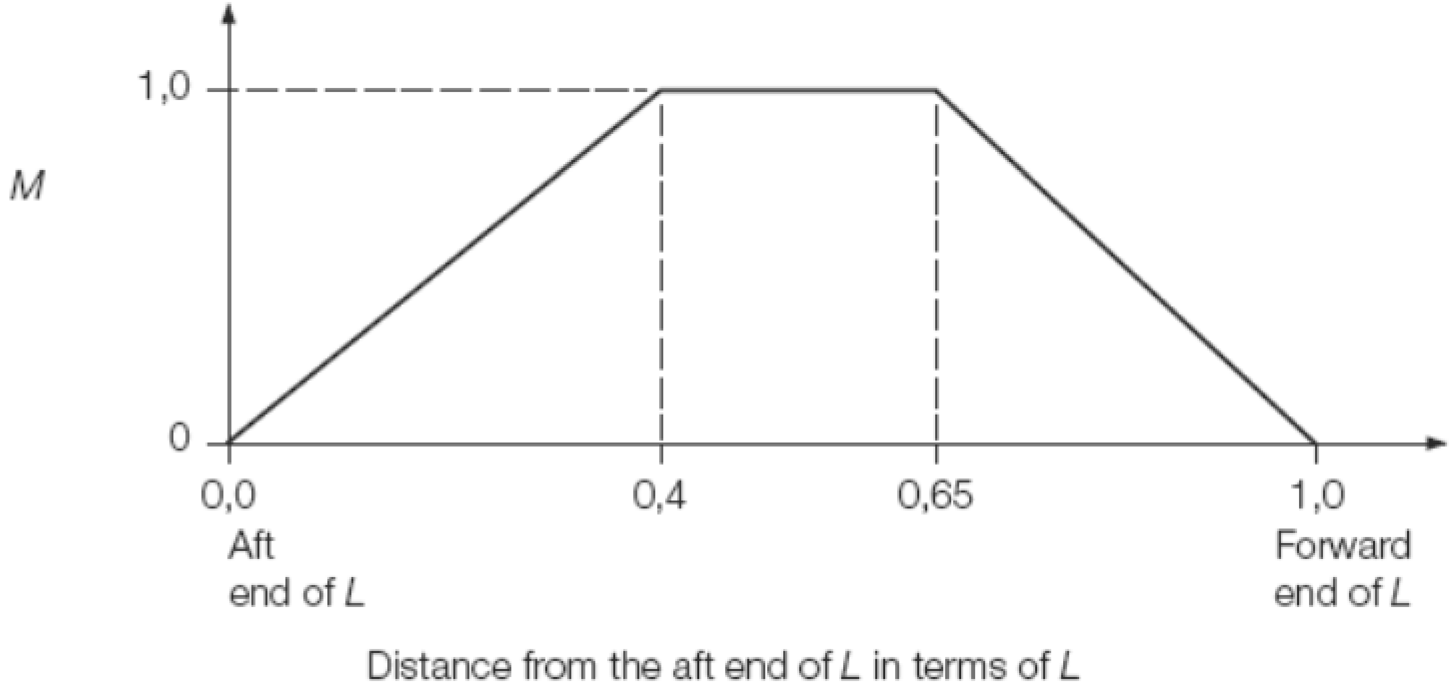
Methodology

2. **Wave condition**
   - Vessel in waves + Still water loads
   - Wave-induced hydro-pressures
   - Higher hogging and sagging loads than in still water
   - Worst case scenario



Classification Society Approach

- Limitations for maximum BM, SF
- Values based on empirical statistics of vessel types
- Midship as the main interest area
- Direct analysis when cruise ship design limits are not covered by Class Rule BM,SF empirical formulae



Quasi-static vs quasi-dynamic

	Quasi-static	**Quasi-dynamic**
Hydrodynamic loading	Static (Point load)	Dynamic (Hydrodynamic pressure)
Vessel in waves	Rigid	Rigid
Inertia effects	×	✓
Vibration effects	×	×
Structural analysis	Static	Static

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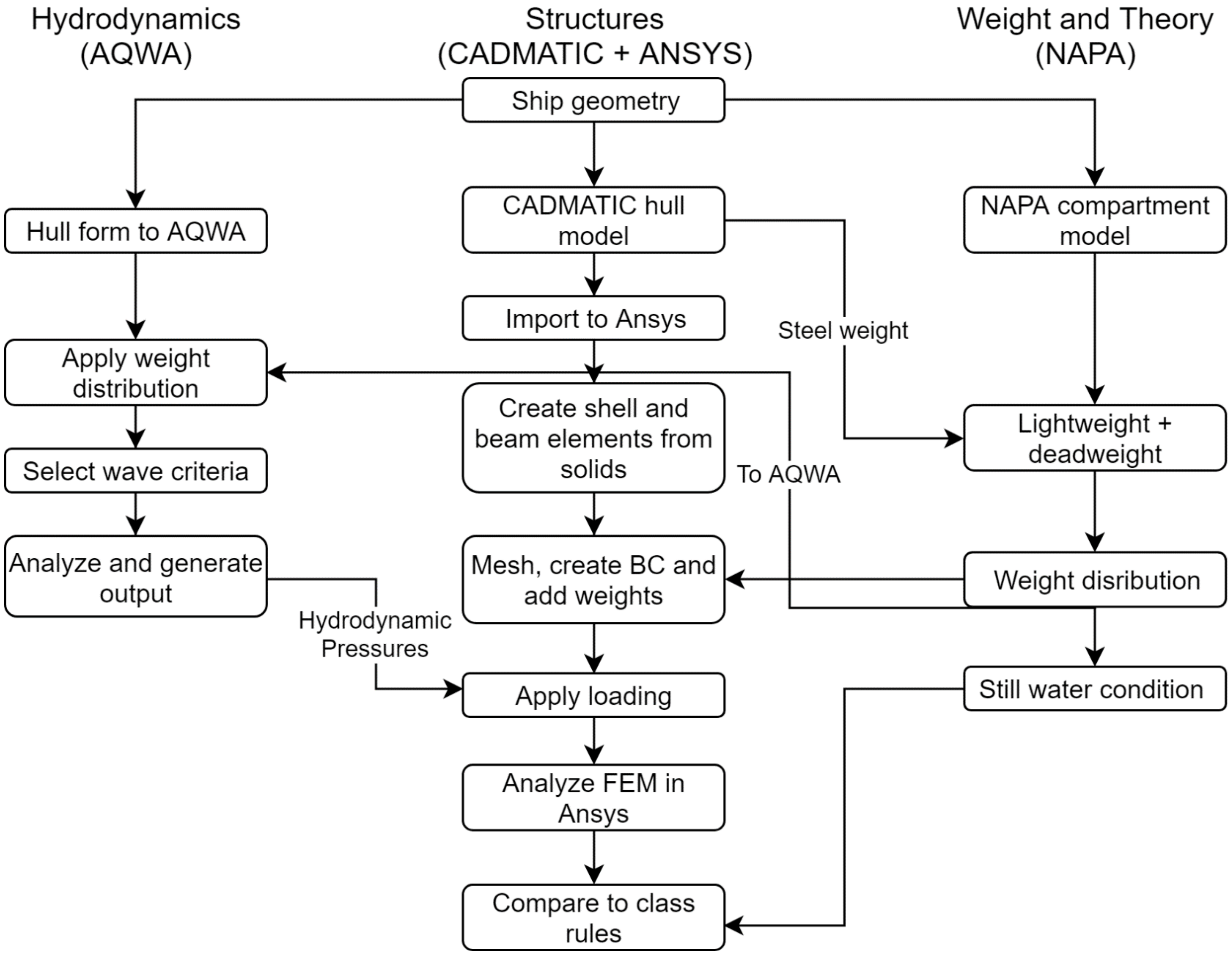
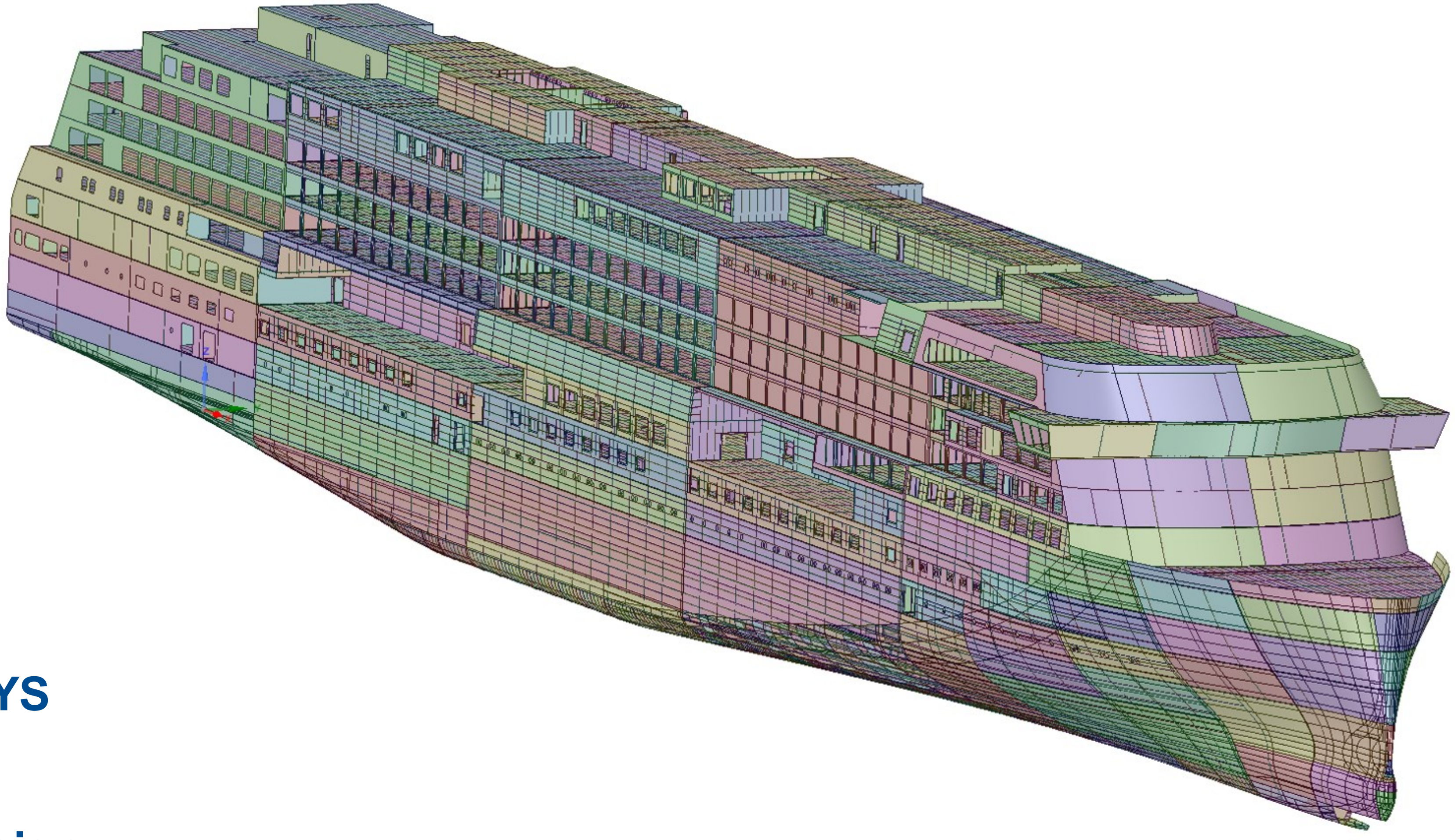
Modelling approach



Case study vessel

- **A cruise ship**
- **Main Dimensions**
  - L = 240 m
  - B = 30 m
  - T_{Design} = 7 m
  - Δ = 32500 t
- **Model was initially made using CADMATIC hull**
- **Then transferred to ANSYS using .step**
- **Accuracy up to basic design**



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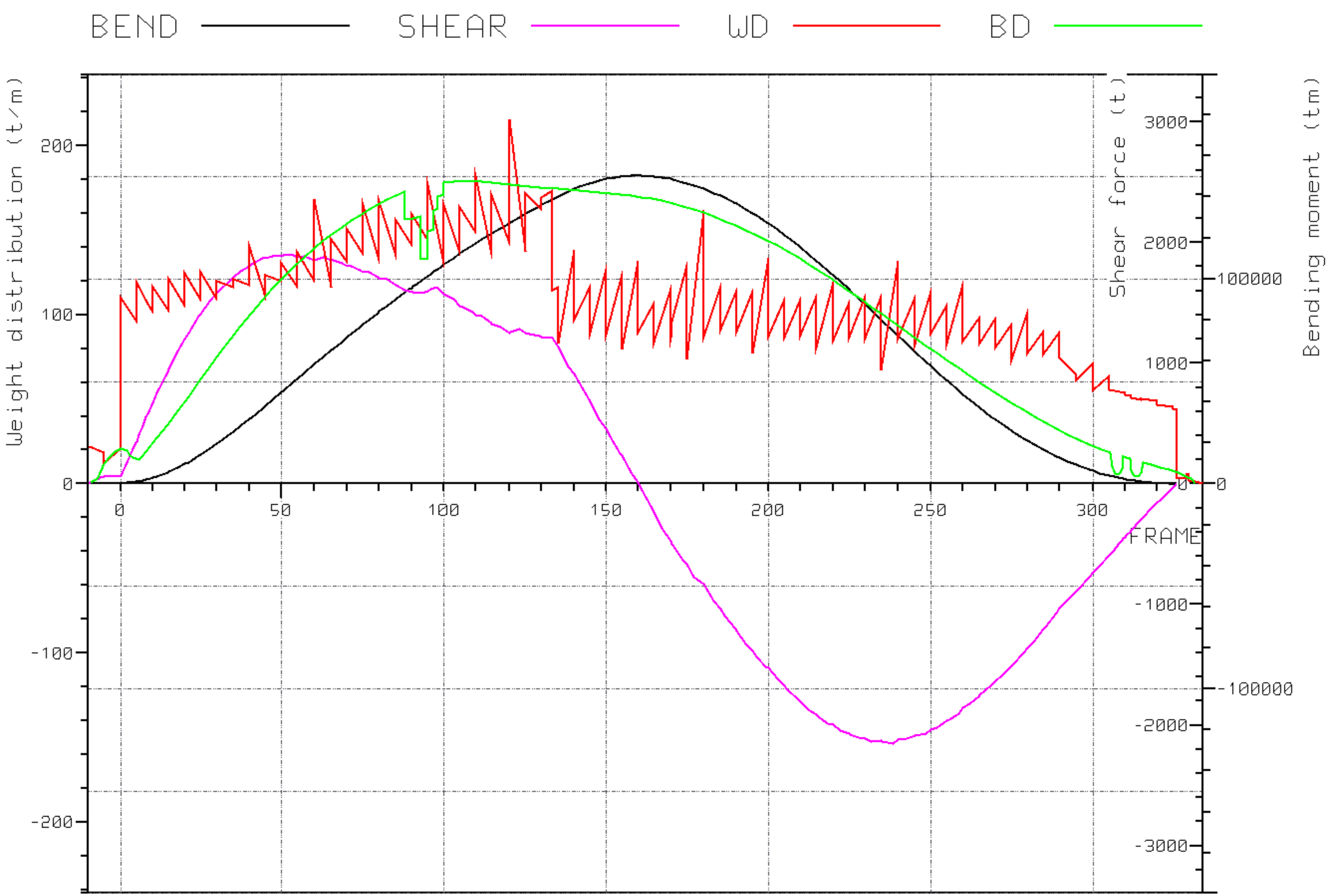
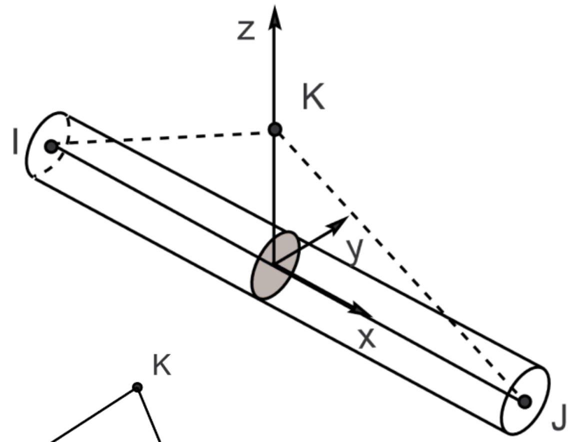
Still water condition

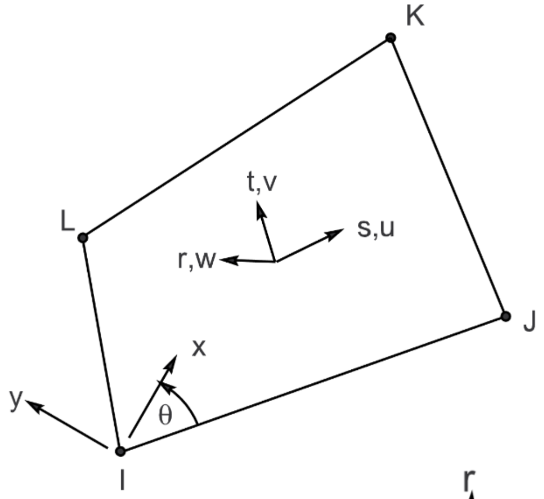


FE Modelling



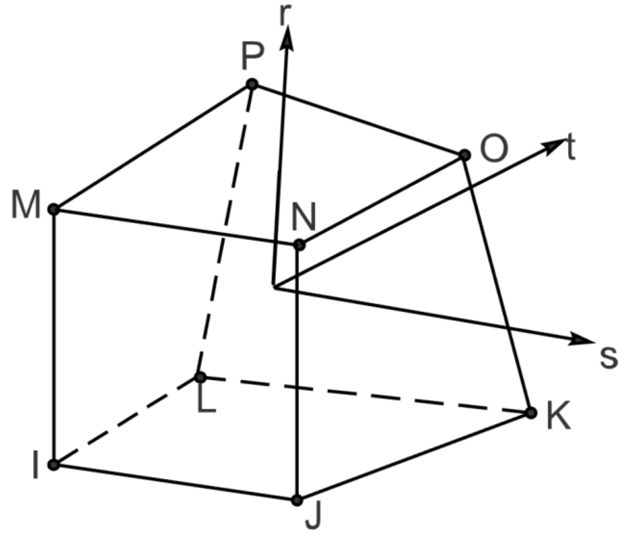
Three finite element idealizations were used :

1. **Beam elements 2 or 3 nodes with 6 DOF**
   - Applicable for slender bodies

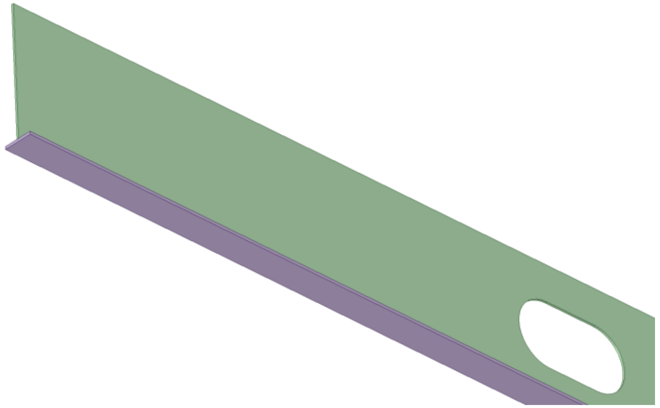


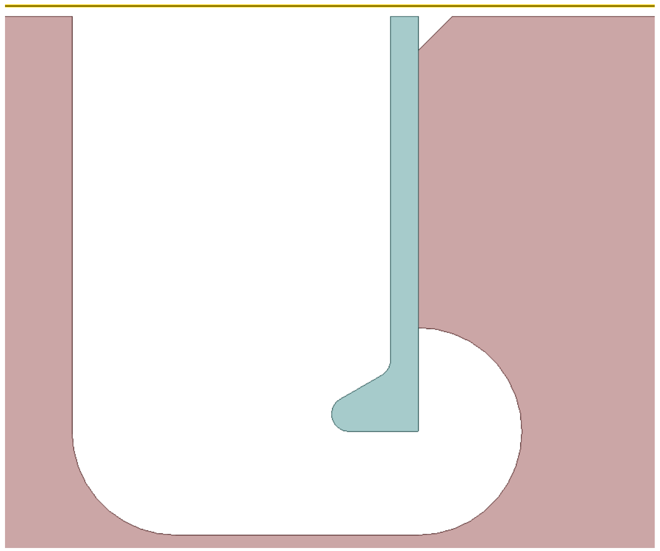
2. **Shell element**
   - At least 3 nodes with 6 DOF
   - Used to model thin-walled bodies

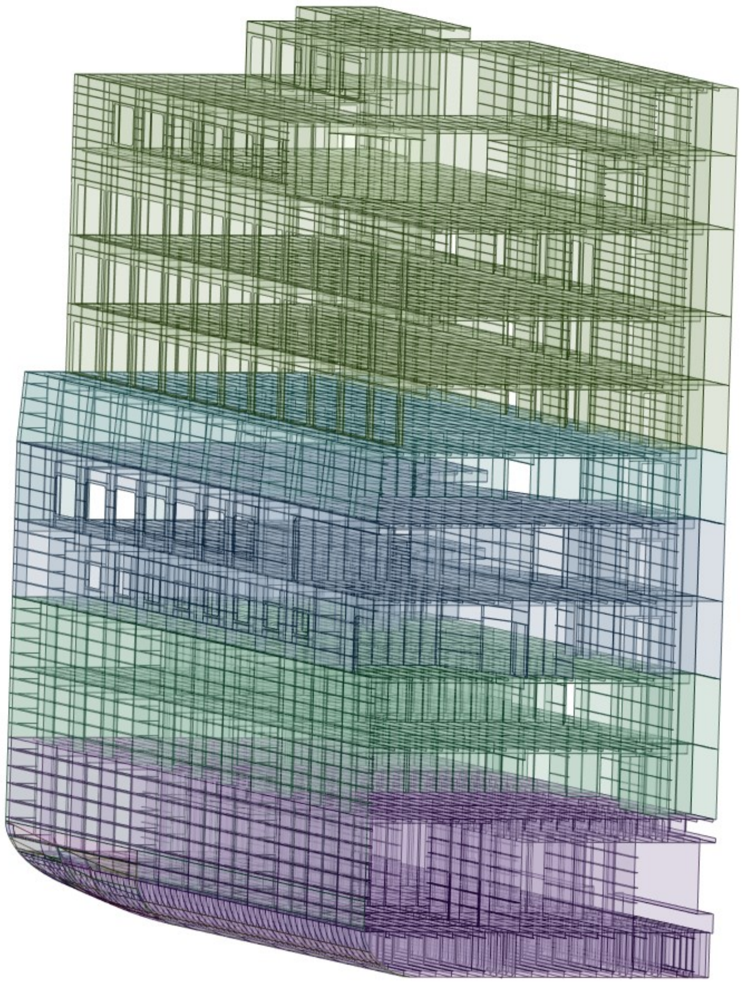
3. **Solid element**
   - At least 4 nodes with 6 DOF
   - Used for complex geometry
   - When other element types are not suitable

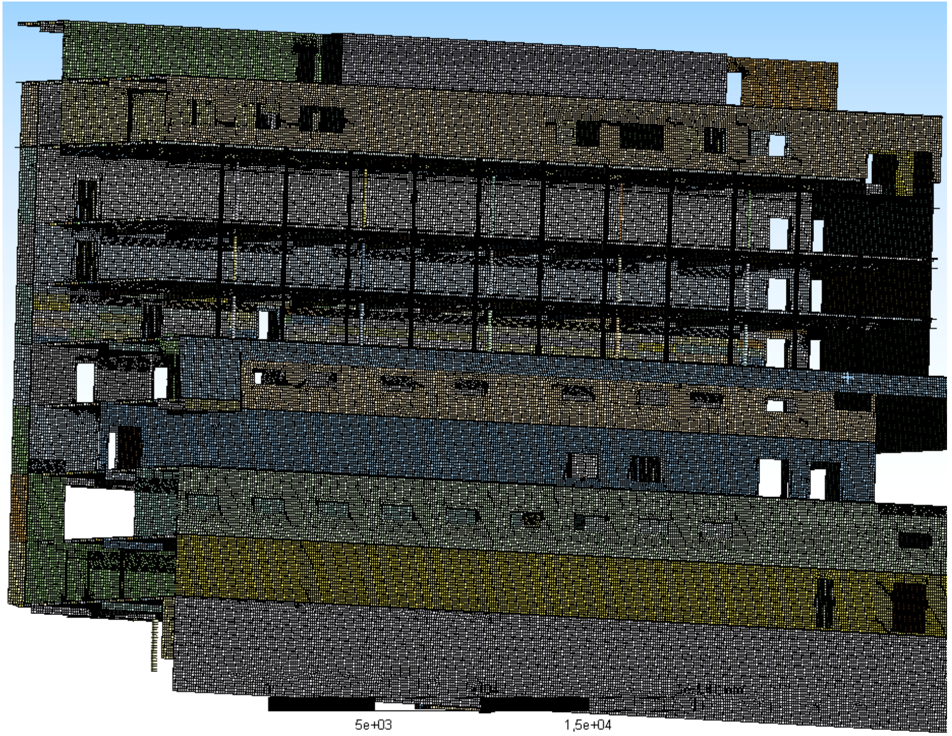


FEM model creation





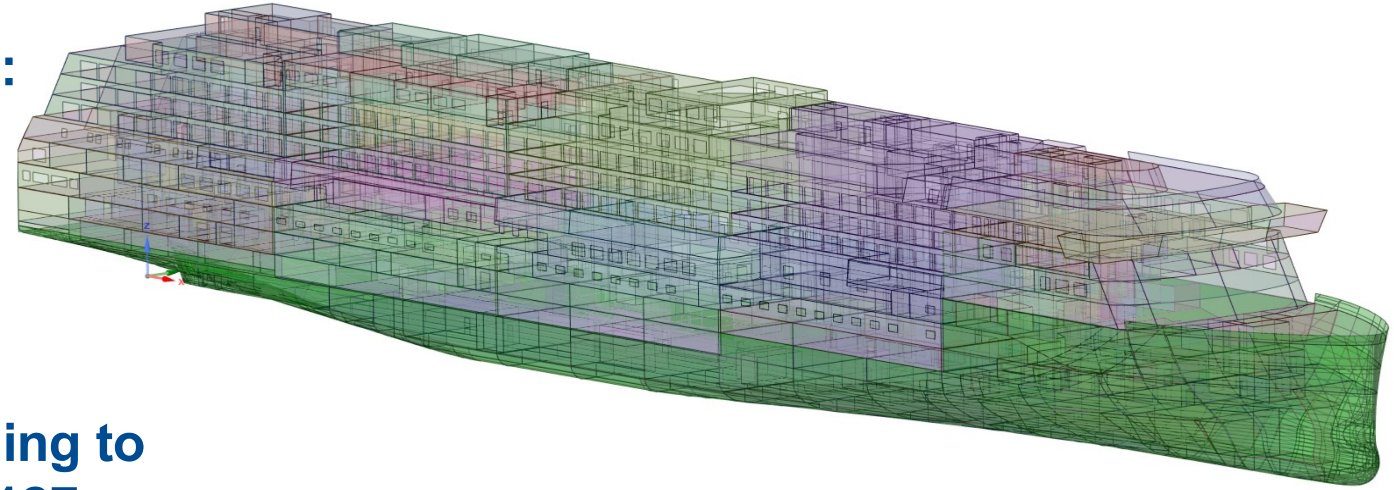




Modelling limitations & BC

FEM model was heavily simplified:

- No stiffeners
- Only shell elements
- Equivalent plate method



Boundary Conditions (BC) according to DNVGL Classification Guideline 0127

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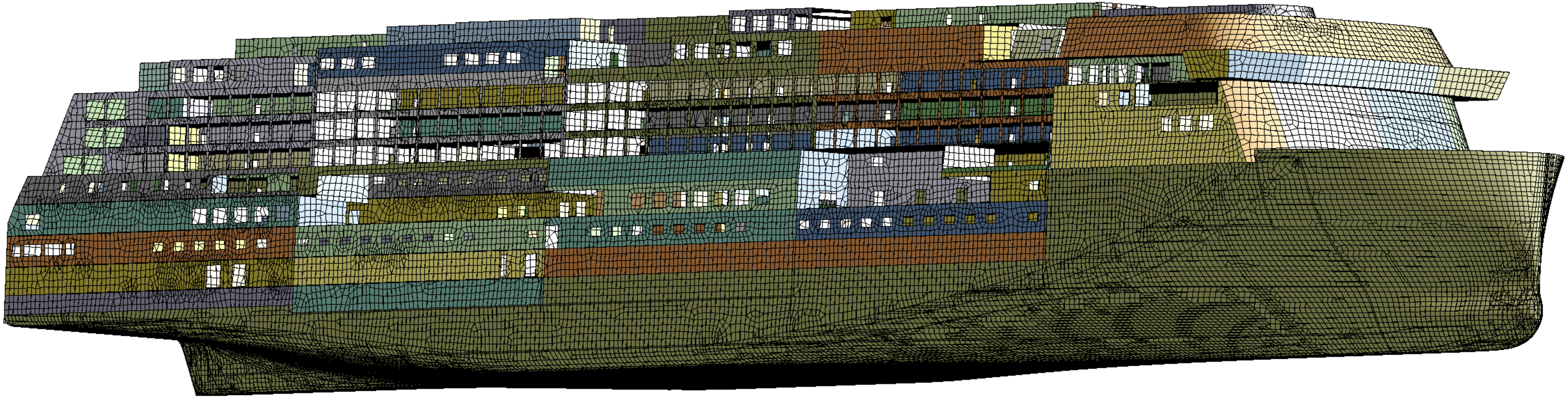
FEM model



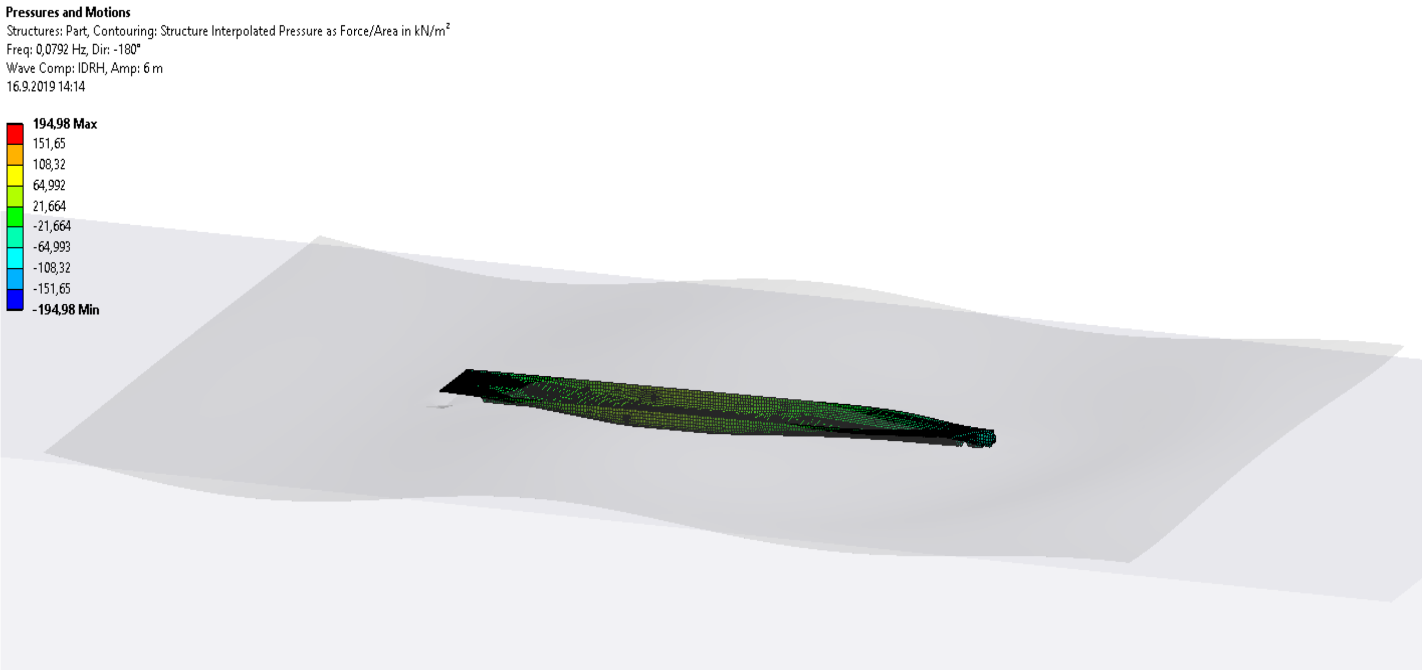
- Mesh size = 750 mm
- Nodes = 252 000
- Elements = 265 000

Hydrodynamic model

ANSYS AQWA:

- 3D panel method
- Simulation of wave diffraction and radiation forces
- Frequency domain with Green's function
- Regular wave analysis
- Both zero and forward speed

Hydrodynamic pressures mapped to the structural model



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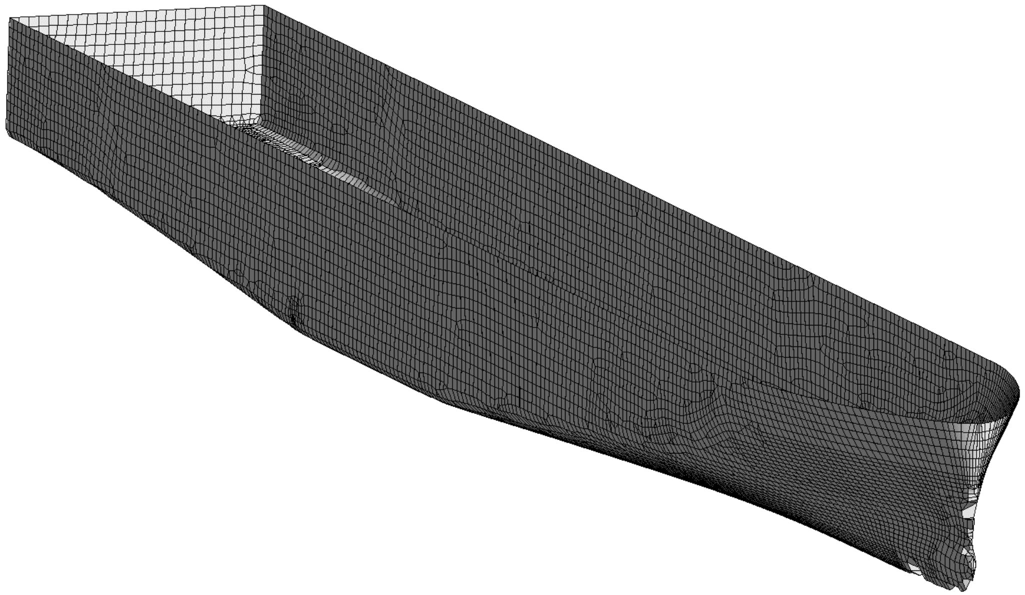
Ansys AQWA

Hydro model meshed with a coarse mesh

- Mesh size = 2 m
- COGz and moments of inertia as input
- Displacement and COG from hydrostatics

Hydrodynamic calculation carried out for:

- 0 and 15 kn forward speed
- -180° and -135 ° headings
- Wave frequencies from 0.015 Hz to 0.41 Hz
- Wave height 1 m and 6 m



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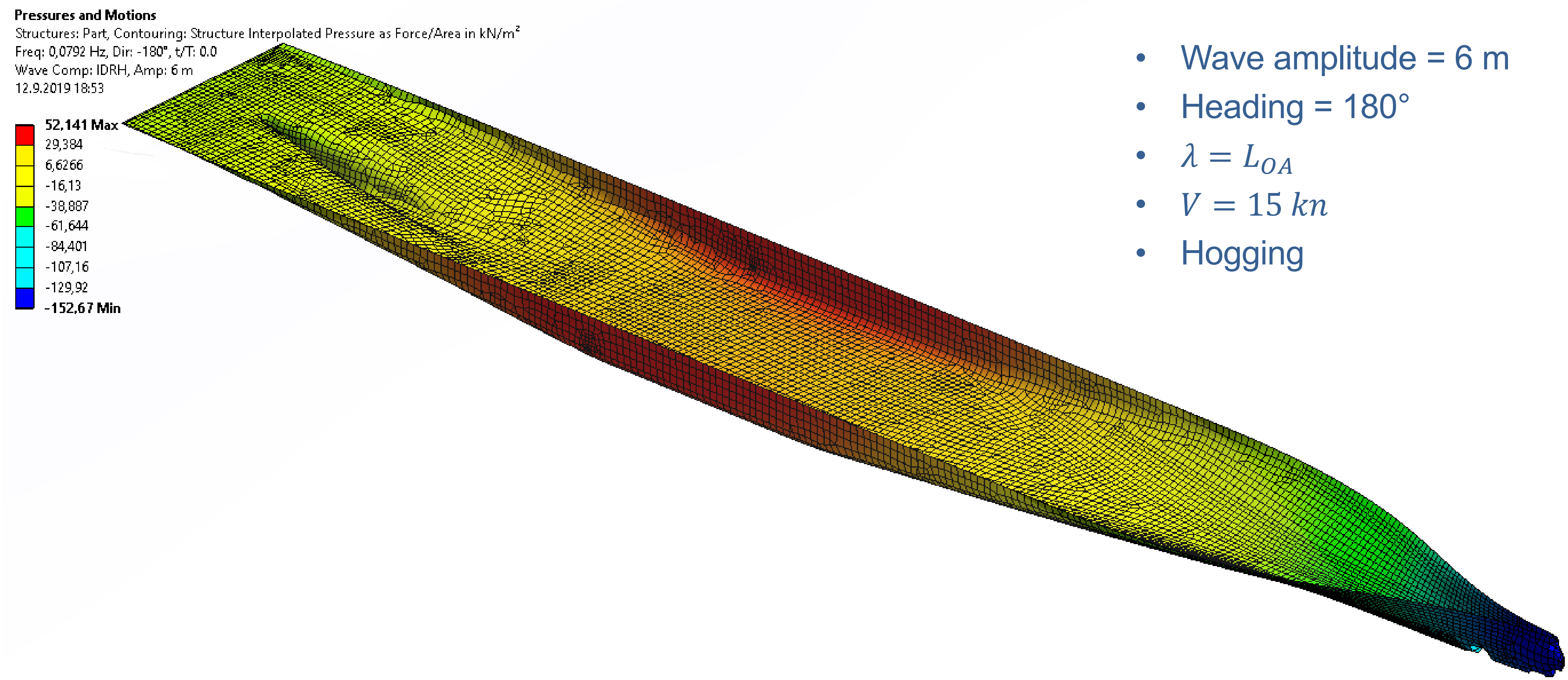
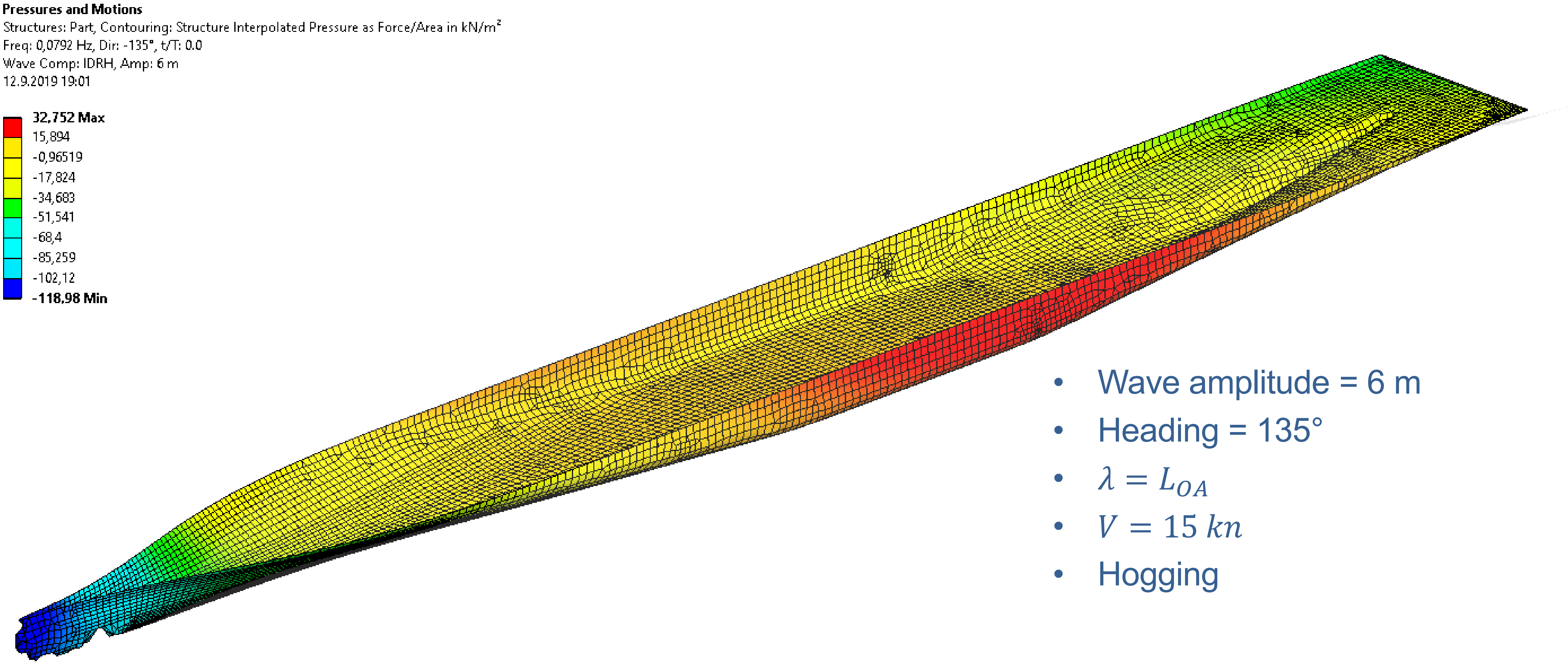
Hydrodynamic pressure



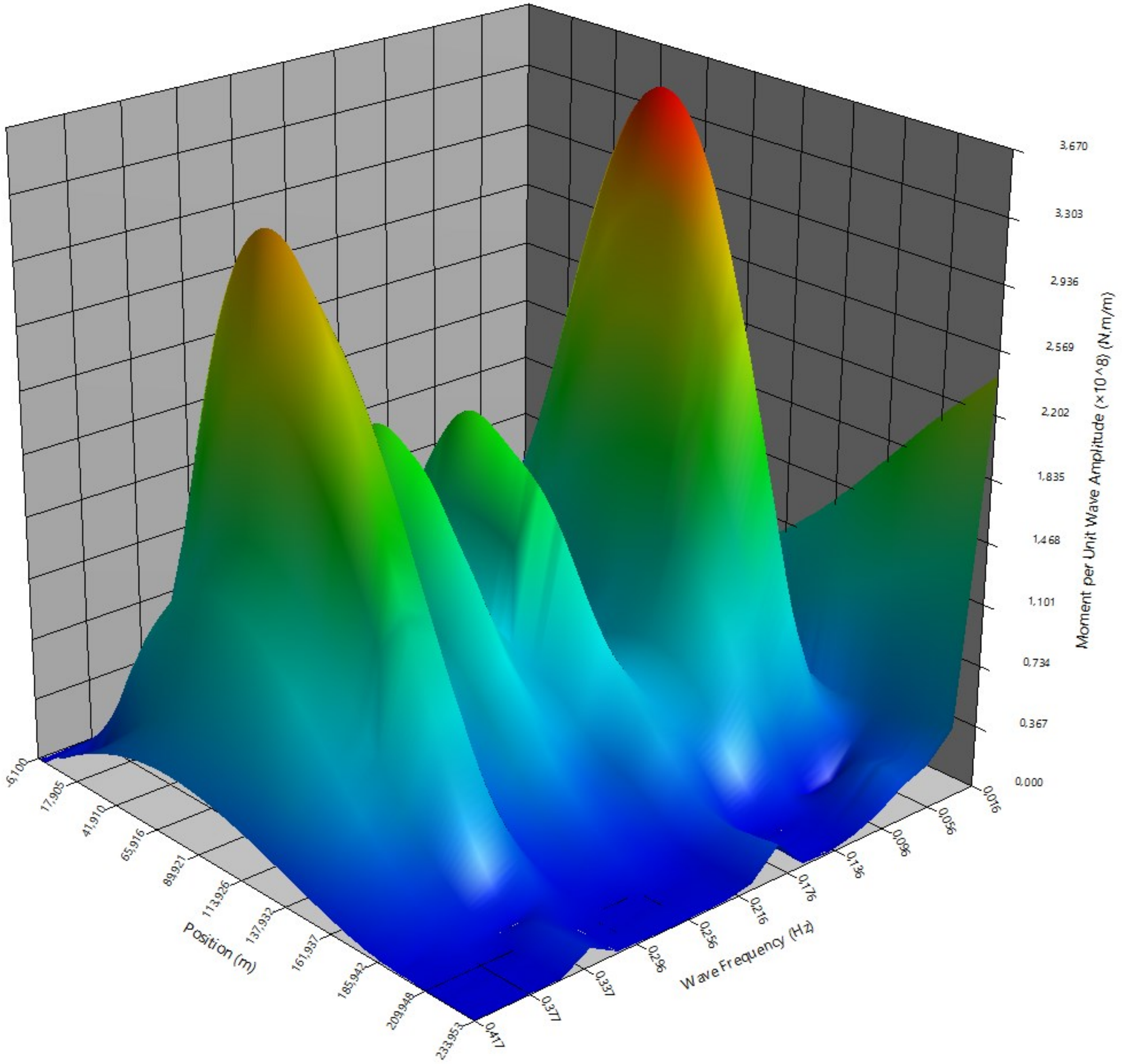
- Wave amplitude = 6 m
- Heading = 180°
- $\lambda = L_{OA}$
- $V = 15\ kn$
- Hogging

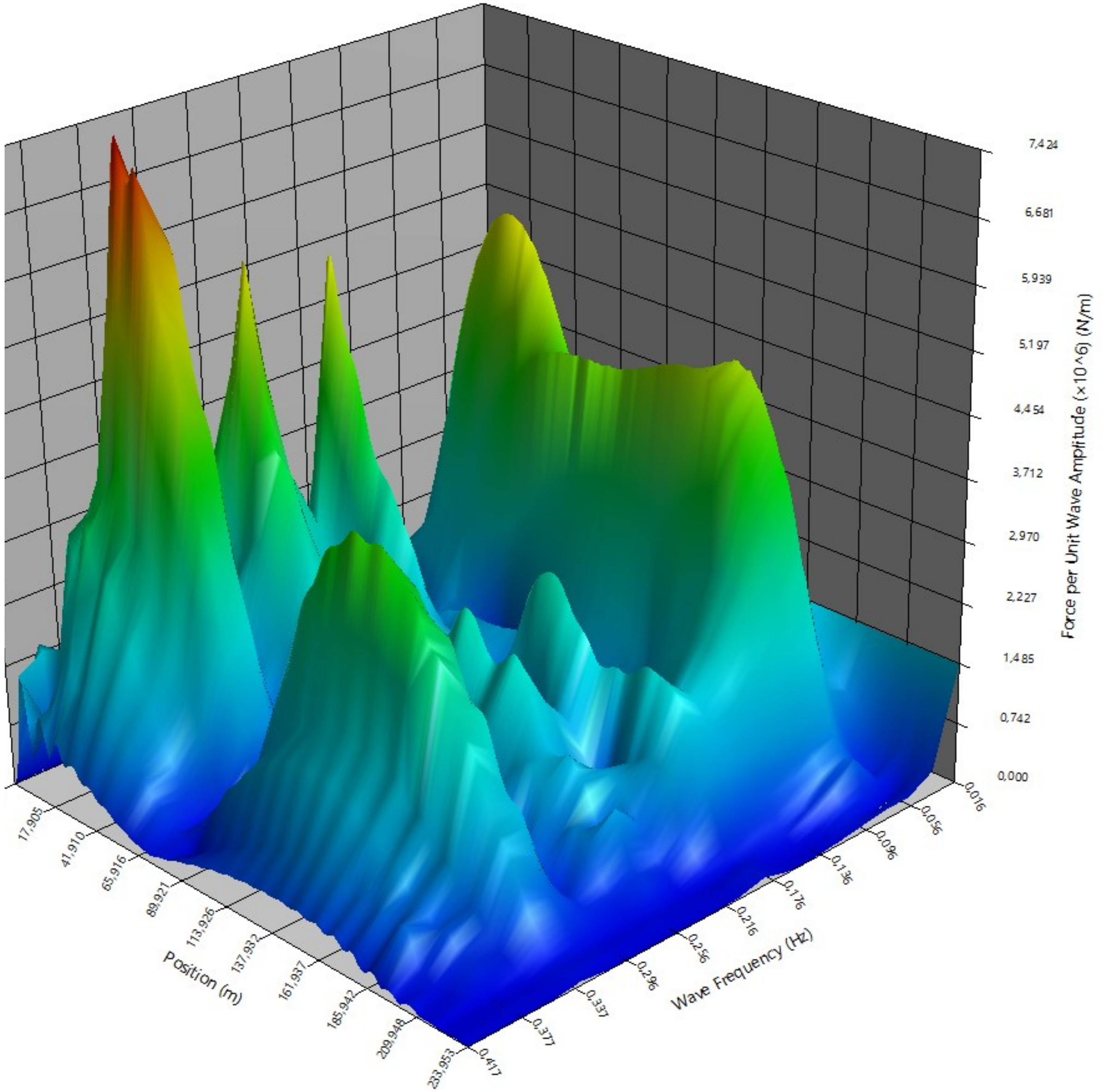
Hydrodynamic pressure



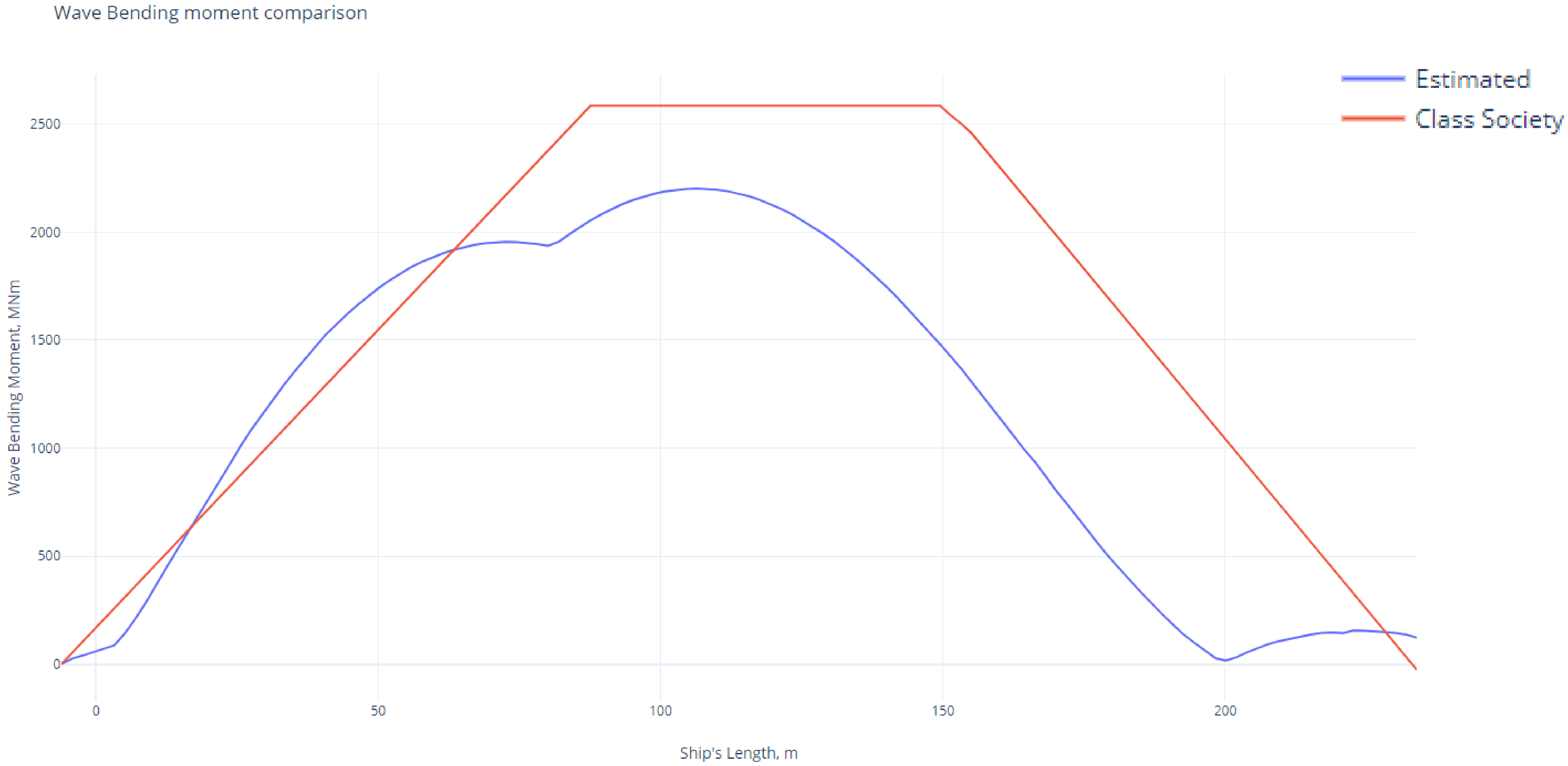
- Wave amplitude = 6 m
- Heading = 135°
- $\lambda = L_{OA}$
- $V = 15\ kn$
- Hogging

Bending moment and shear force RAO

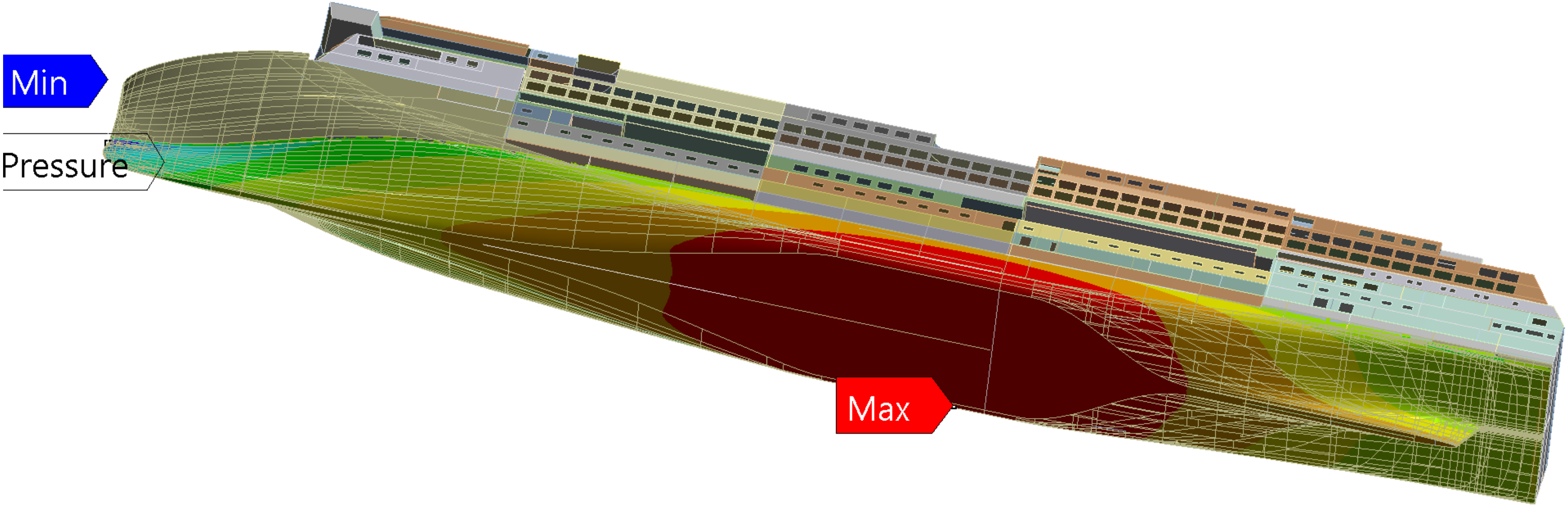




Wave bending moment



Mapped pressures



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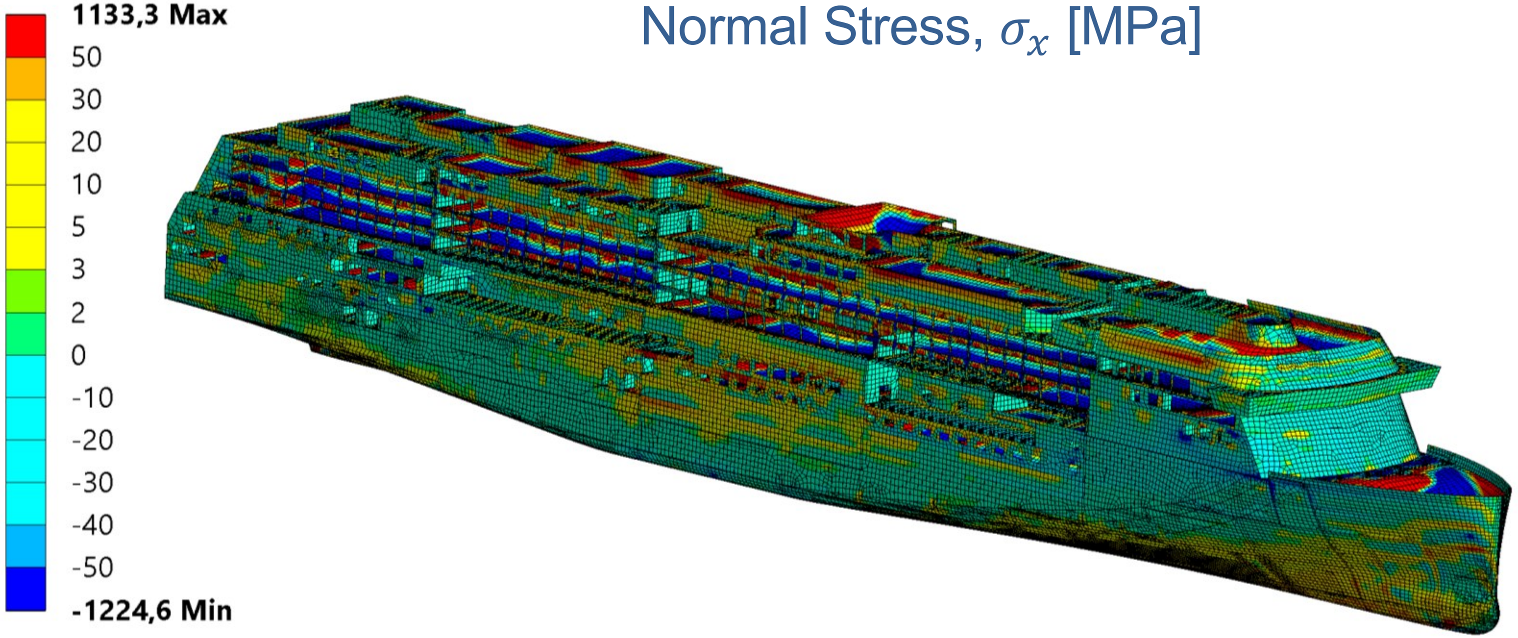
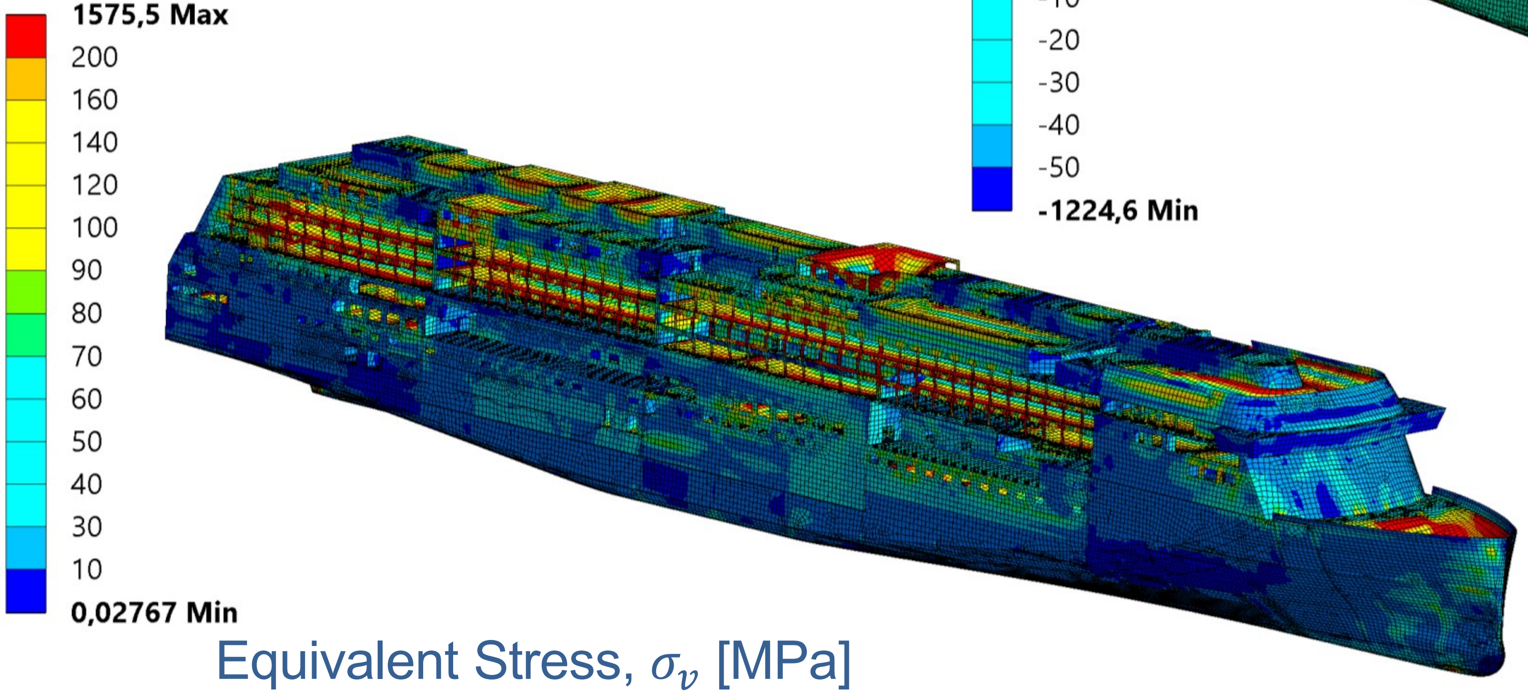
Stress results

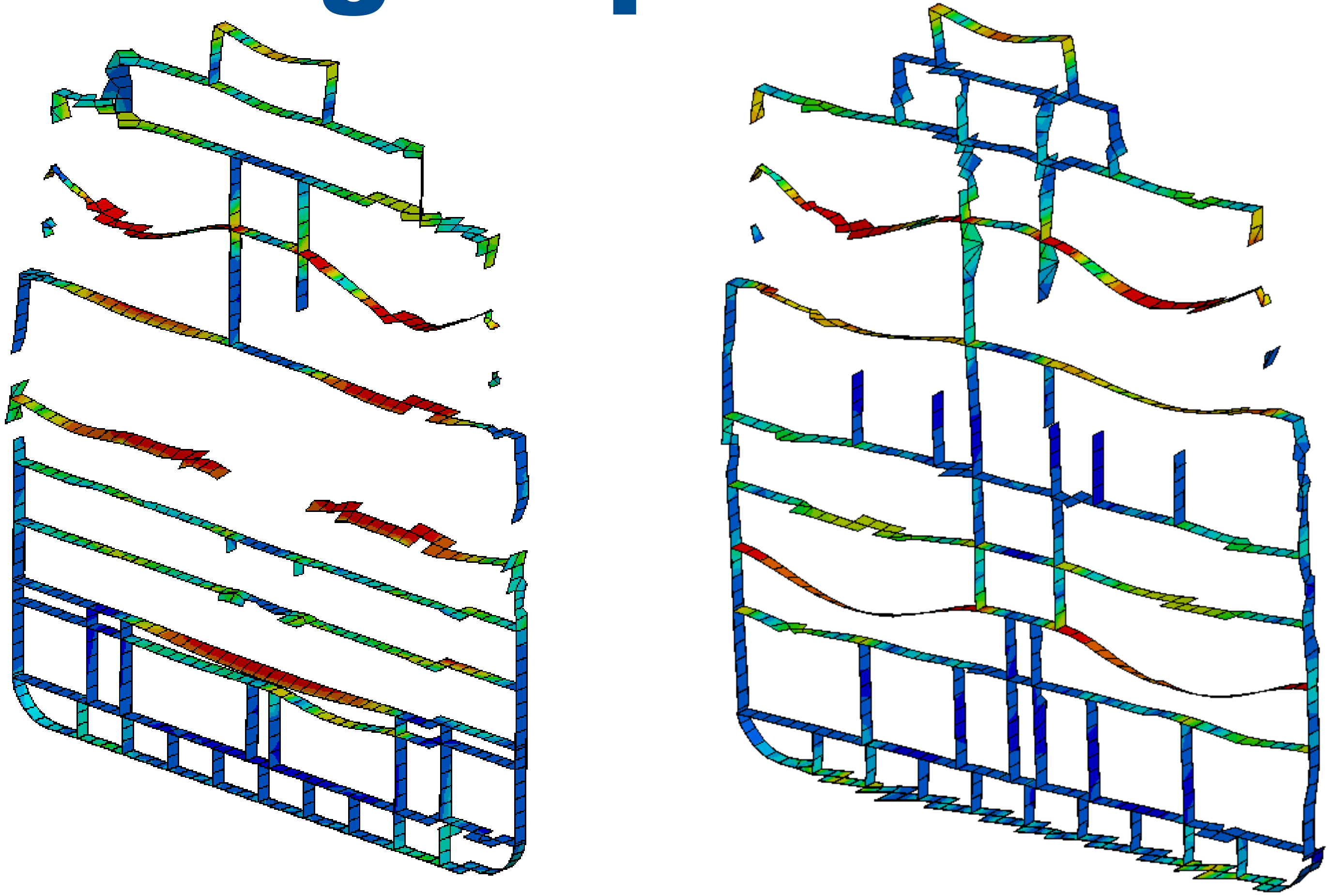


Normal Stress, σ_x [MPa]



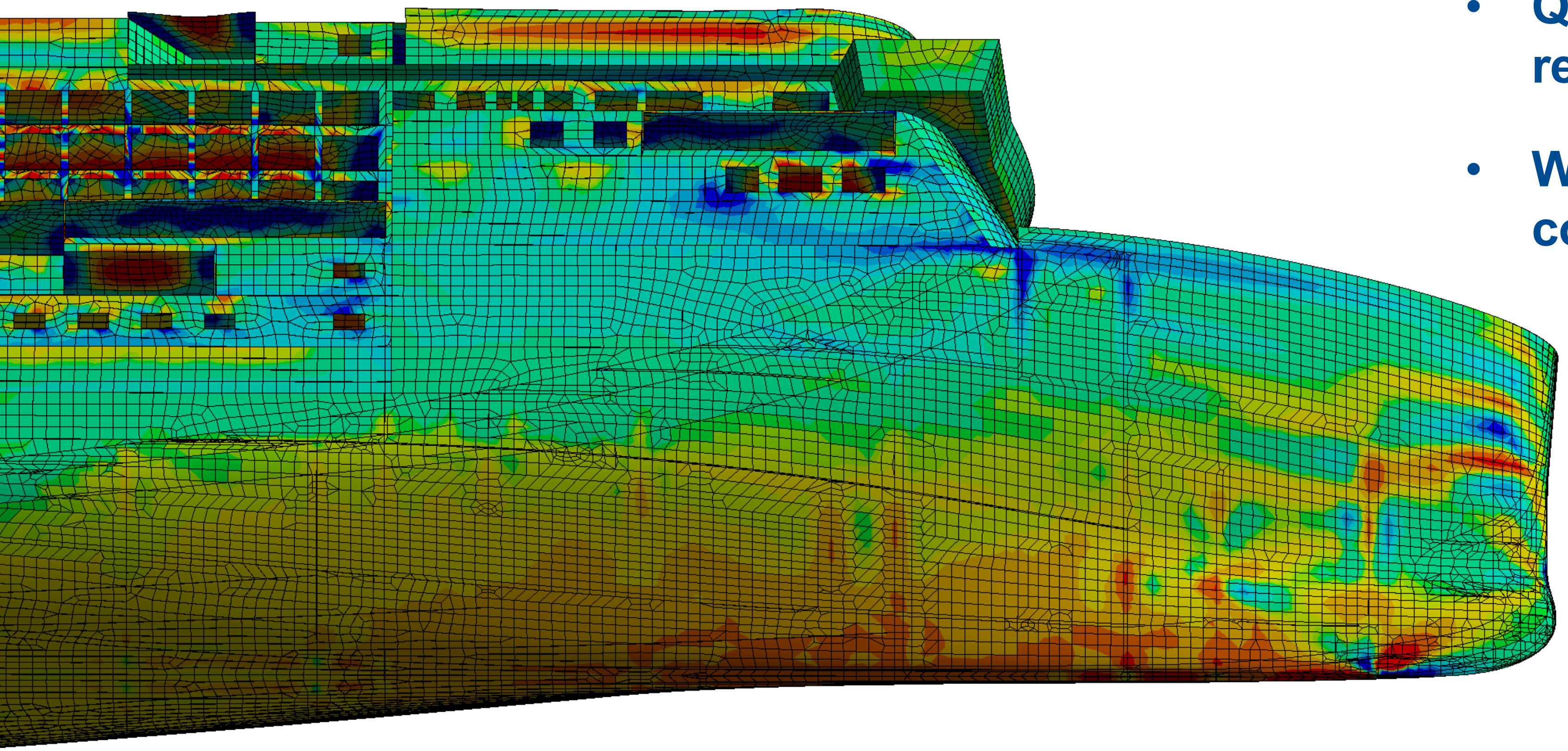
Equivalent Stress, σ_v [MPa]

Average equivalent stress



	Frame #124	Frame #145	Frame #175	Whole model
σ_e, [MPa]	72.4	88.4	65.8	58.8

Conclusions



- **As a result global strength analysis procedure was carried out**
- **Quasi-dynamic approach used in regular waves**
- **Wave bending moment results compared to class rules**
  - Different outcomes using direct and class methods

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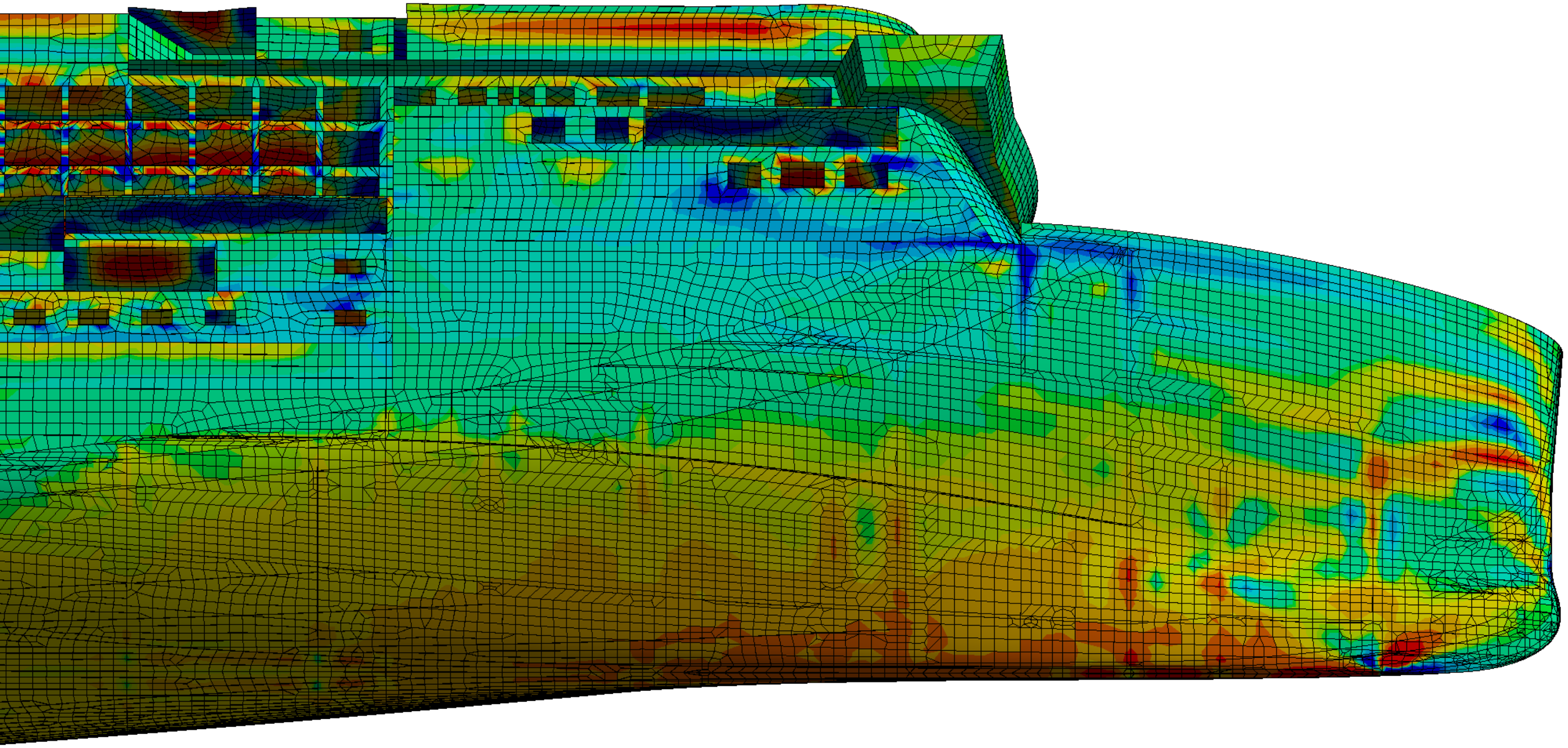
Future development



- **Elaborate on the FEM model**
  - Fully involving equivalent plate method
  - Adding pillars
  - Adding weight elements and balancing models

Whole setup can later be used for fatigue or buckling estimation

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