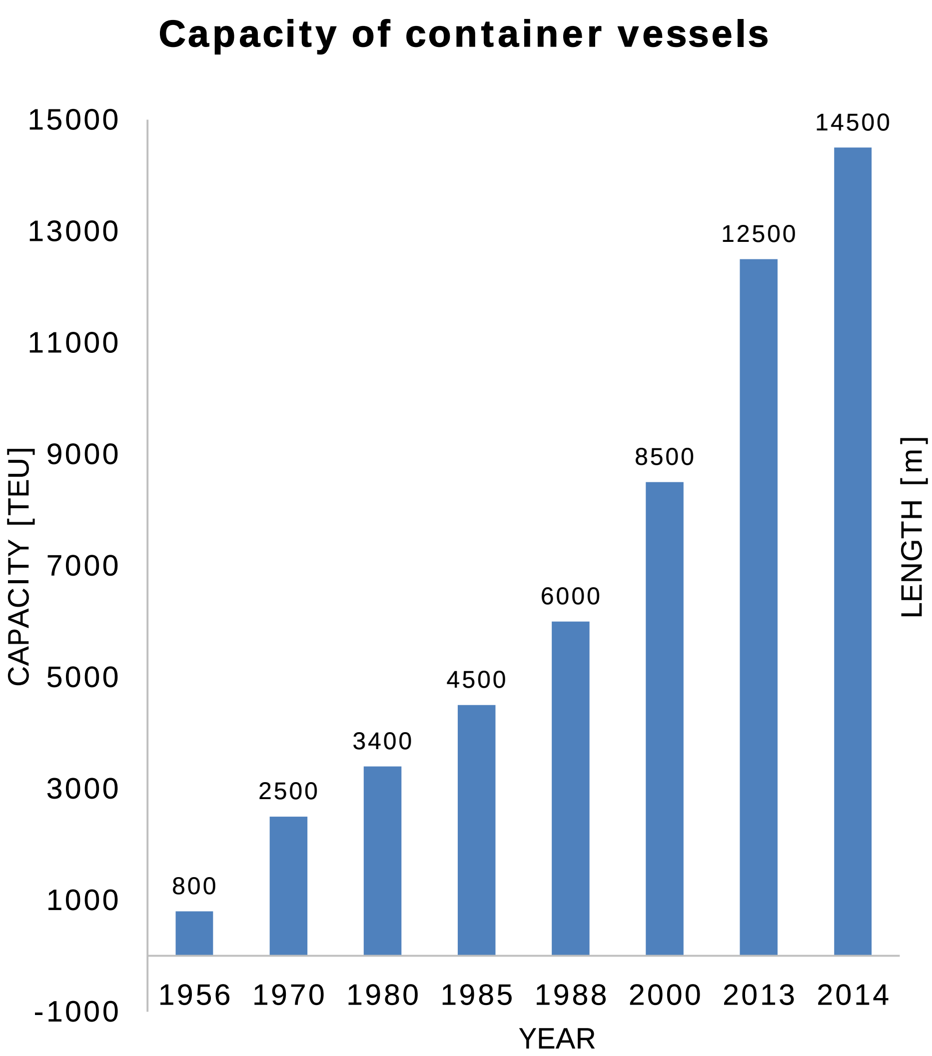
Hull Girder Ultimate Strength of a Ship Using Nonlinear FE Method

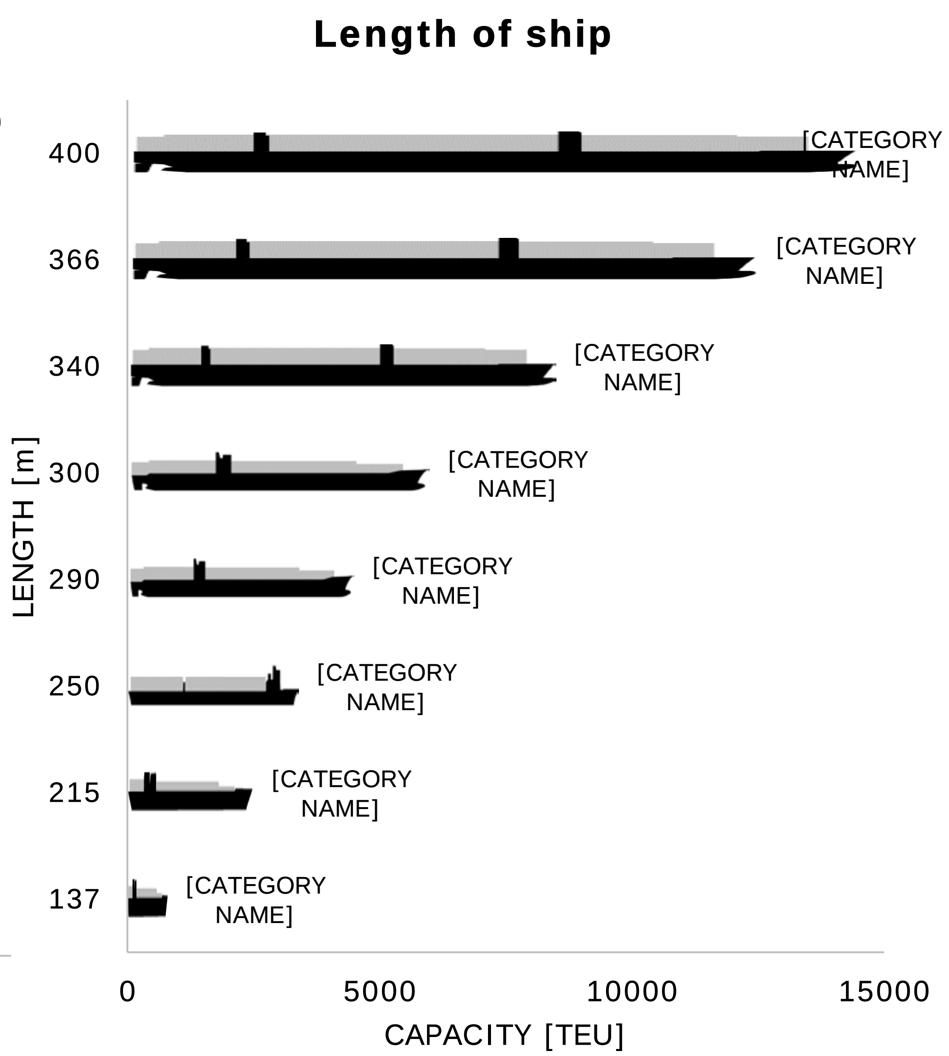
Supervisors
Mr. Ionel Darie Dipl.-Ing.(DNV GL SE)
Prof. Patrick Keading (URO)
Dr.-Ing. Thomas Lindemann (URO)

Presented by
Hemanand Kalyanasundaram

Université de Liège
EMship Advanced Design
Centrale Nantes
Universität Rostock Traditio et Innovatio
DNV·GL

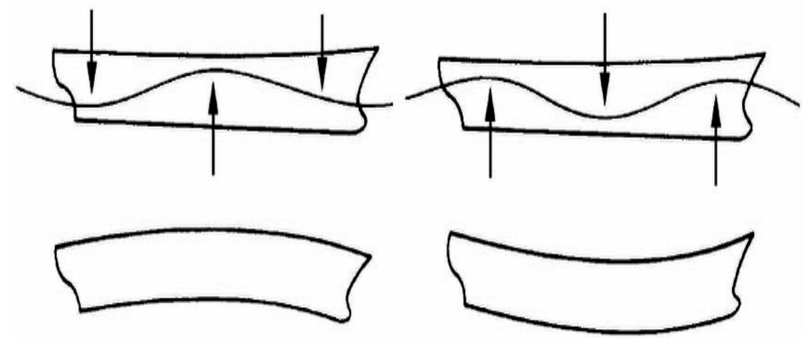
Evolution of Container ships



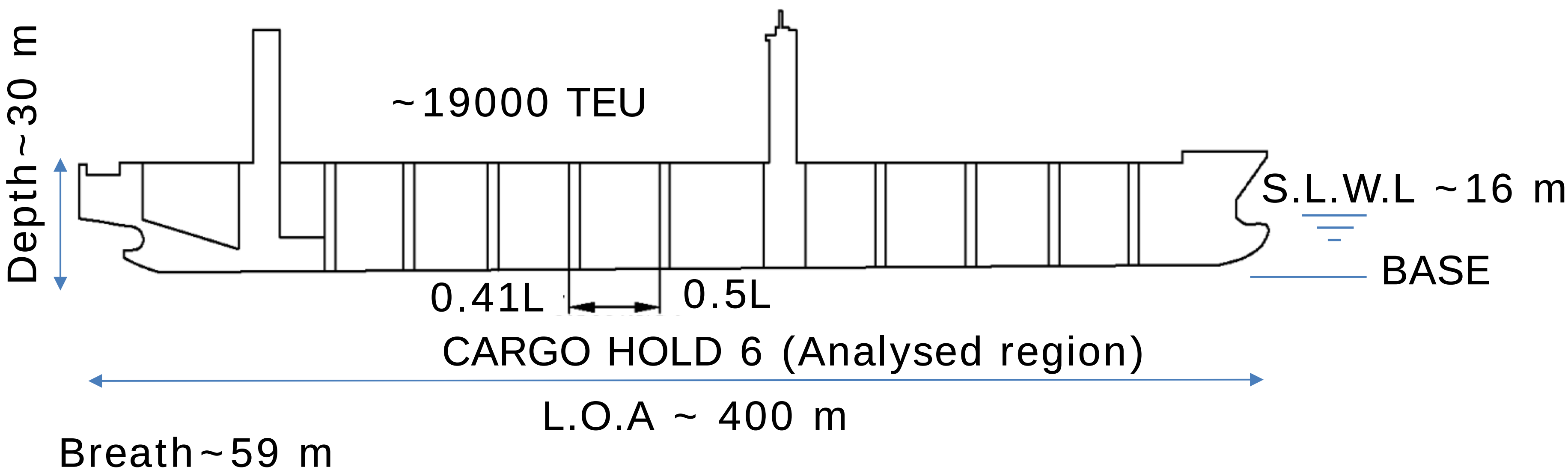


Reference: https://people.hofstra.edu/geotrans/eng/ch3en/conc3en/containerships.html

Motivation and parameters of analyzed ship



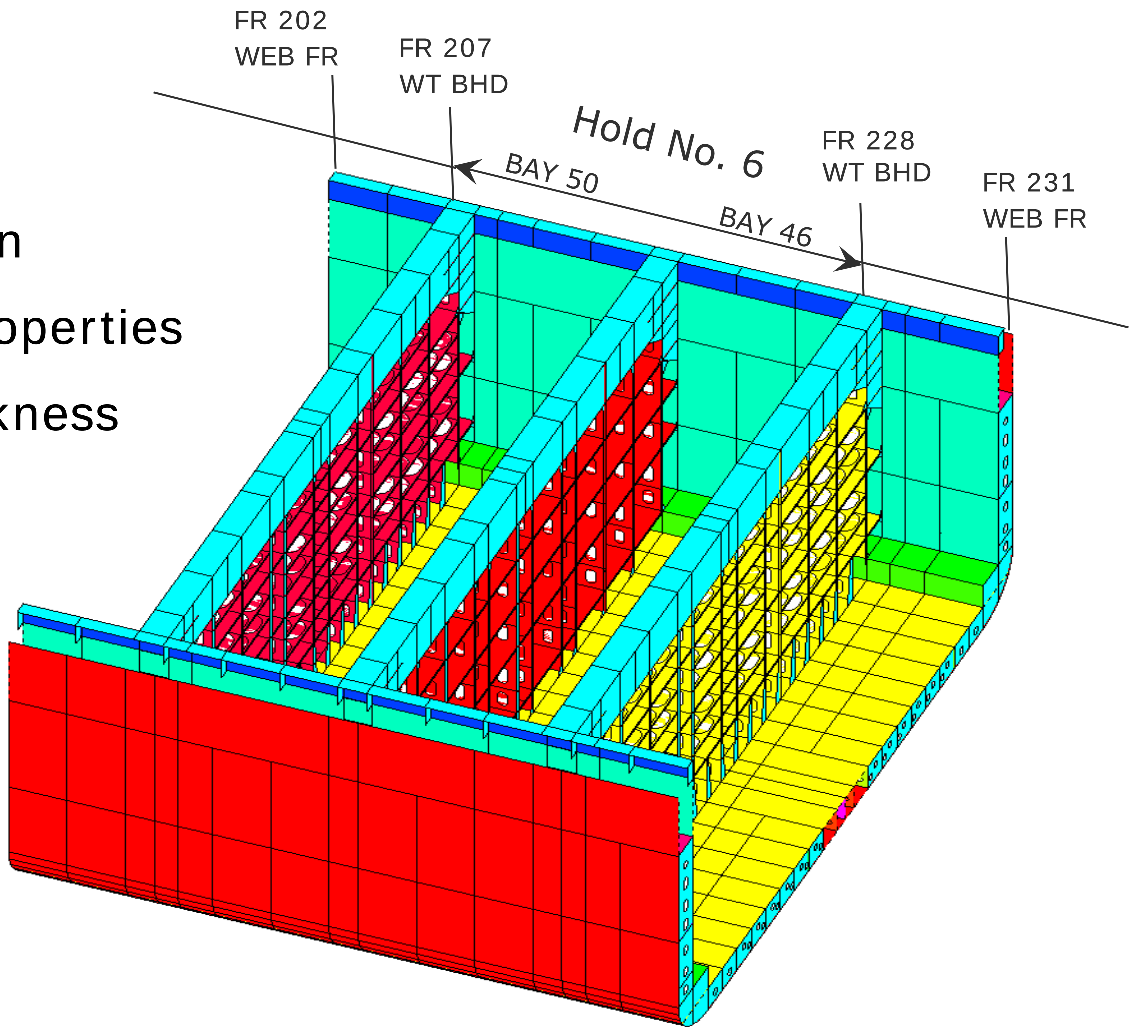
Hogging sagging



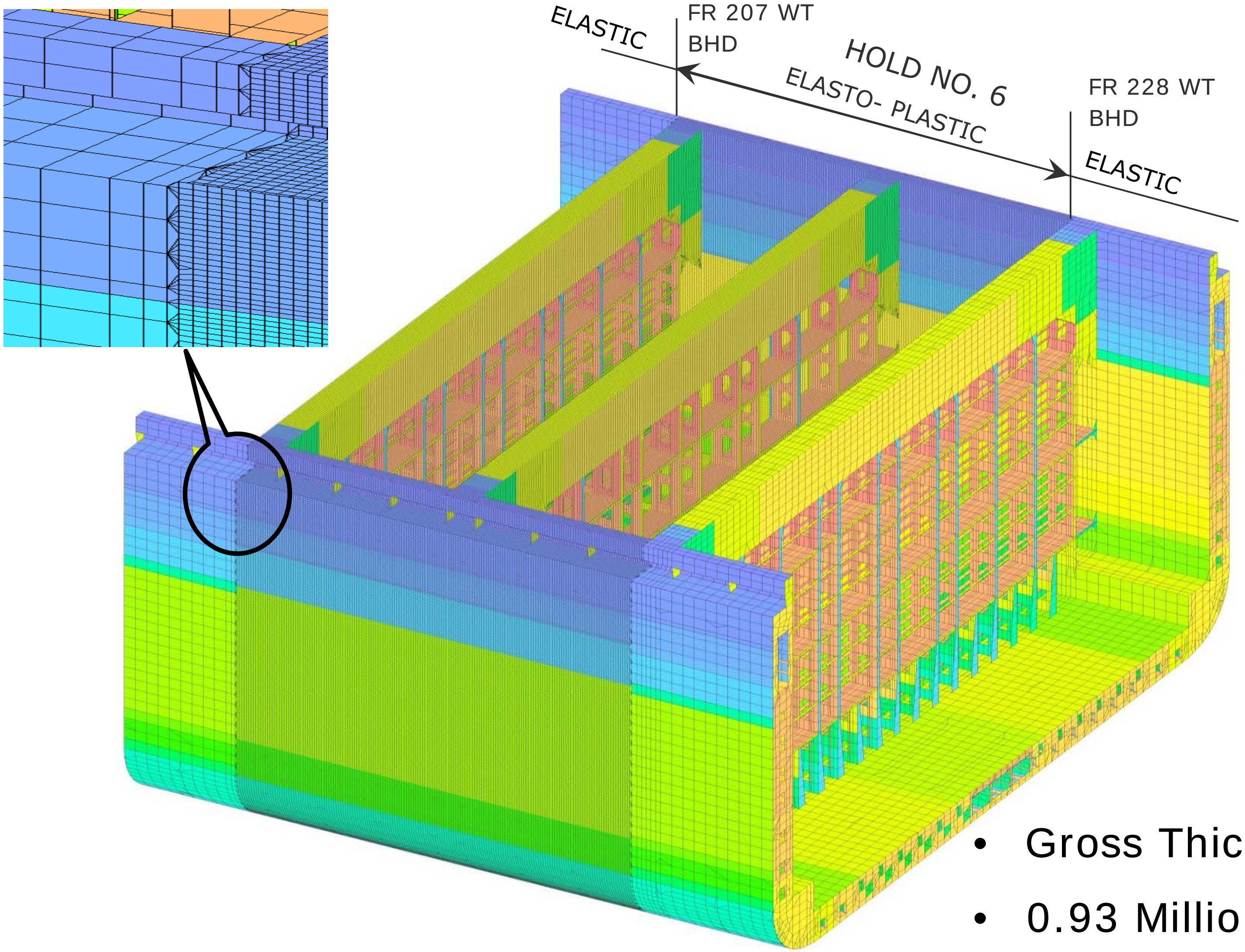
Reference:
http://gcaptain.com/mol-comfort-incident-photos/
https://www.researchgate.net/figure/228891097_fig2_Figure-2-Hogging-and-sagging-of-ship-hull

CAD model preparation

- -GL Poseidon
- -Material properties
- -Gross Thickness
- -Cutouts

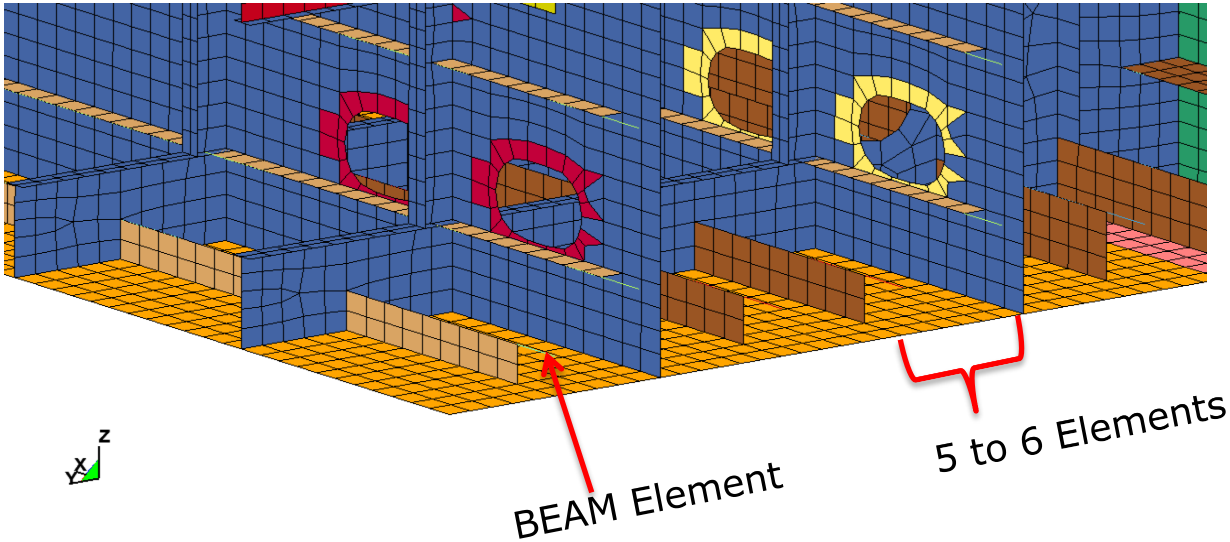


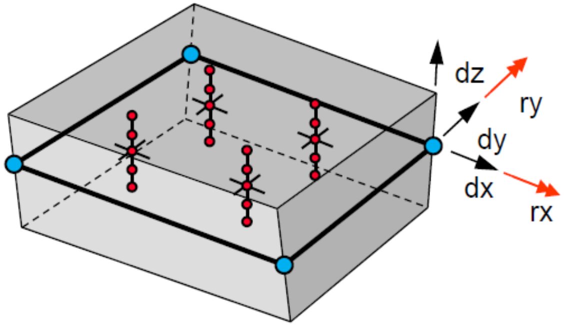
FE model preparation – Cargo hold model



- Gross Thickness - 0.5 t_c
- 0.93 Million nodes

Mesh size and considering nonlinearities





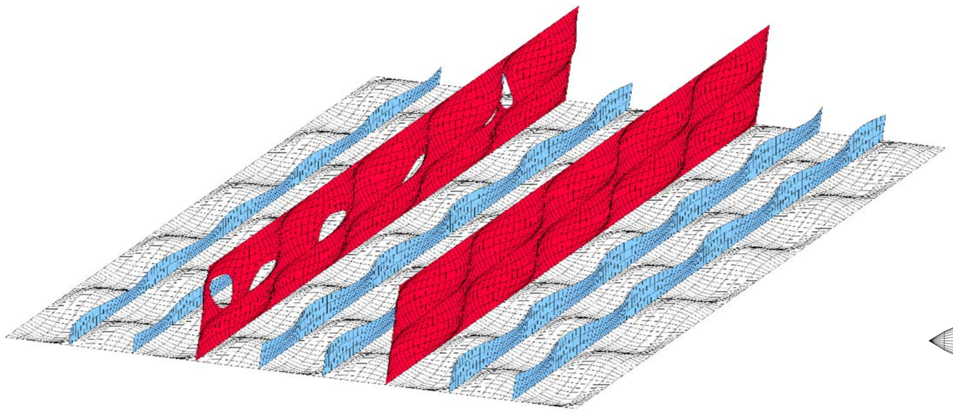
Shell 16

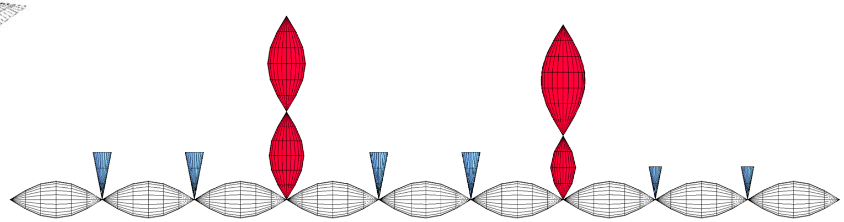
Nonlinearities	Analysed area	Other
Geometric	Shell 16 (plates + stiffener web)	Shell 2 (plates)
	Beam (Stiffener flange)	Truss (stiffener)
Material	Elasto-plastic (Bilinear model) E_t =1000 Mpa	Elastic

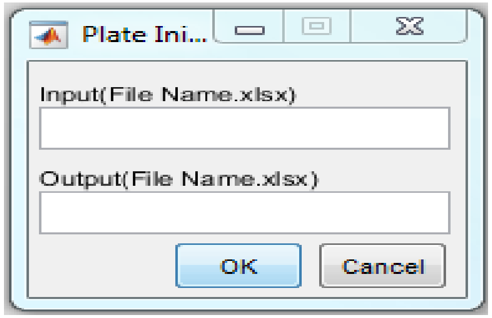
Reference:
https://www.dynamore.de/de/download/papers/2013-ls-dyna-forum/documents/review-of-shell-element-formulations

Modeling geometrical initial imperfections

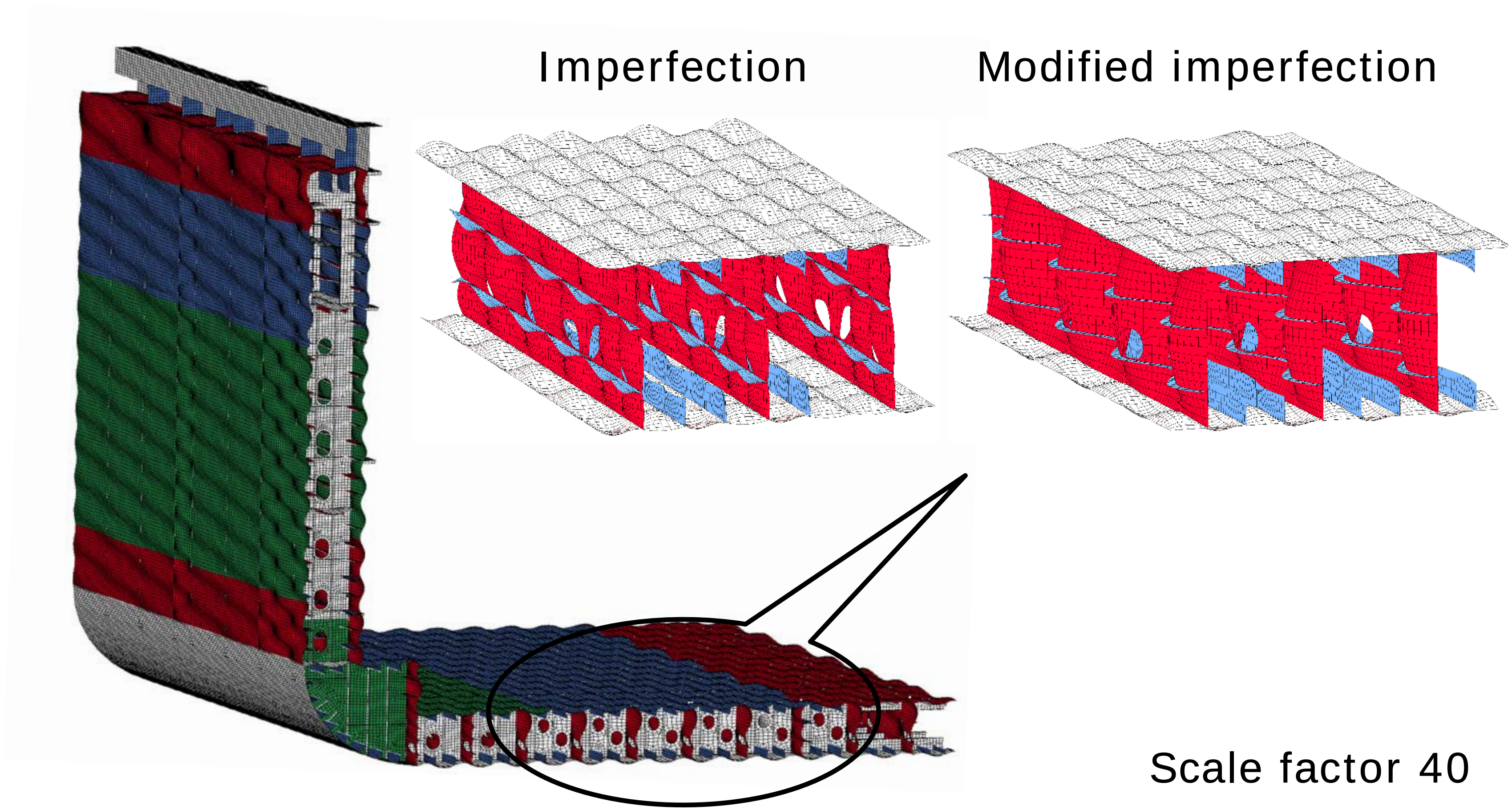
- Maximum deflection $\delta_{plate} = \frac{b}{200}$ $\delta_{stiffweb} = \frac{a}{1000}$
  - a Frame spacing
  - b Stiffener spacing





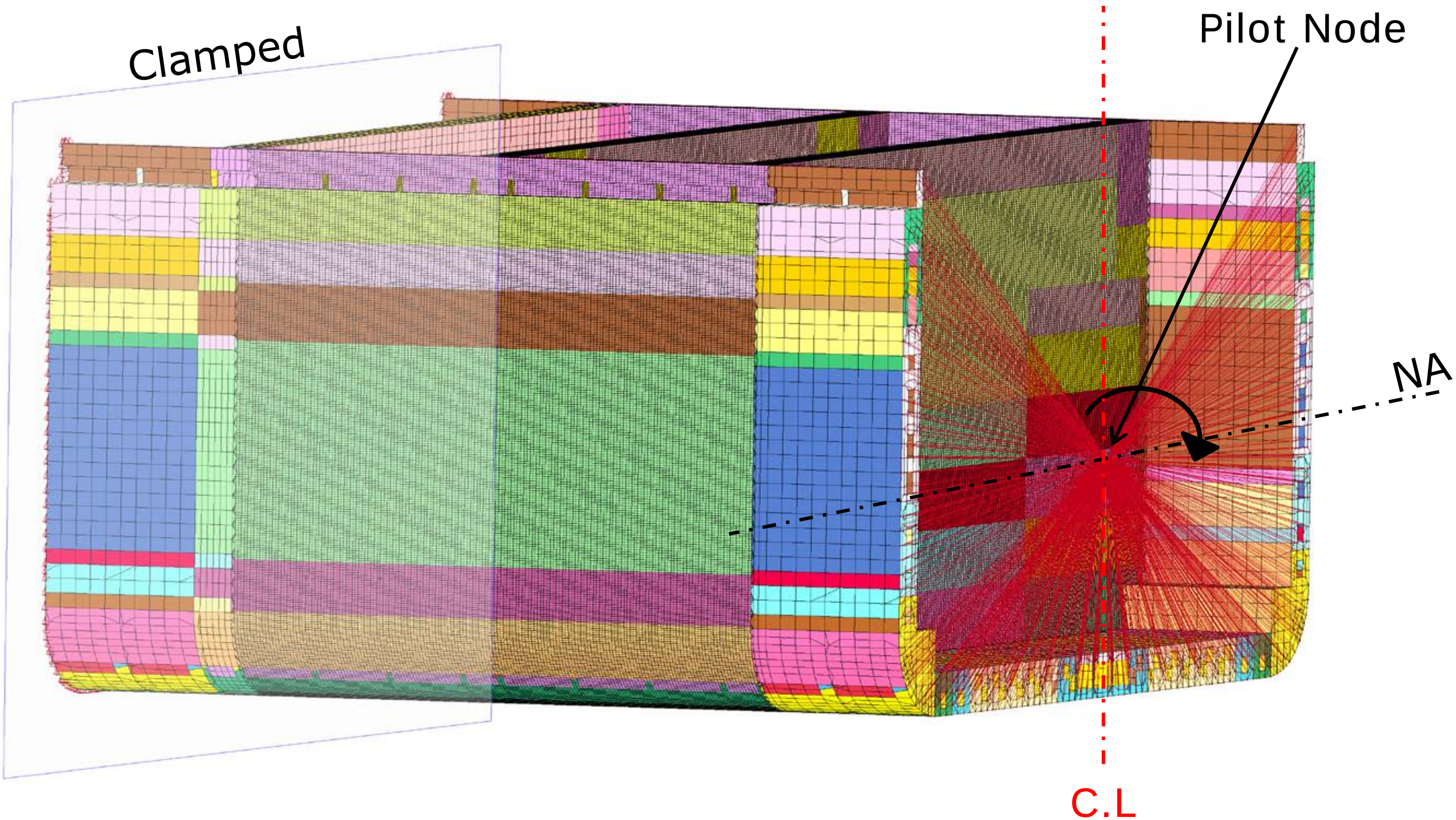


Imperfection on FE model - Section view



Scale factor 40

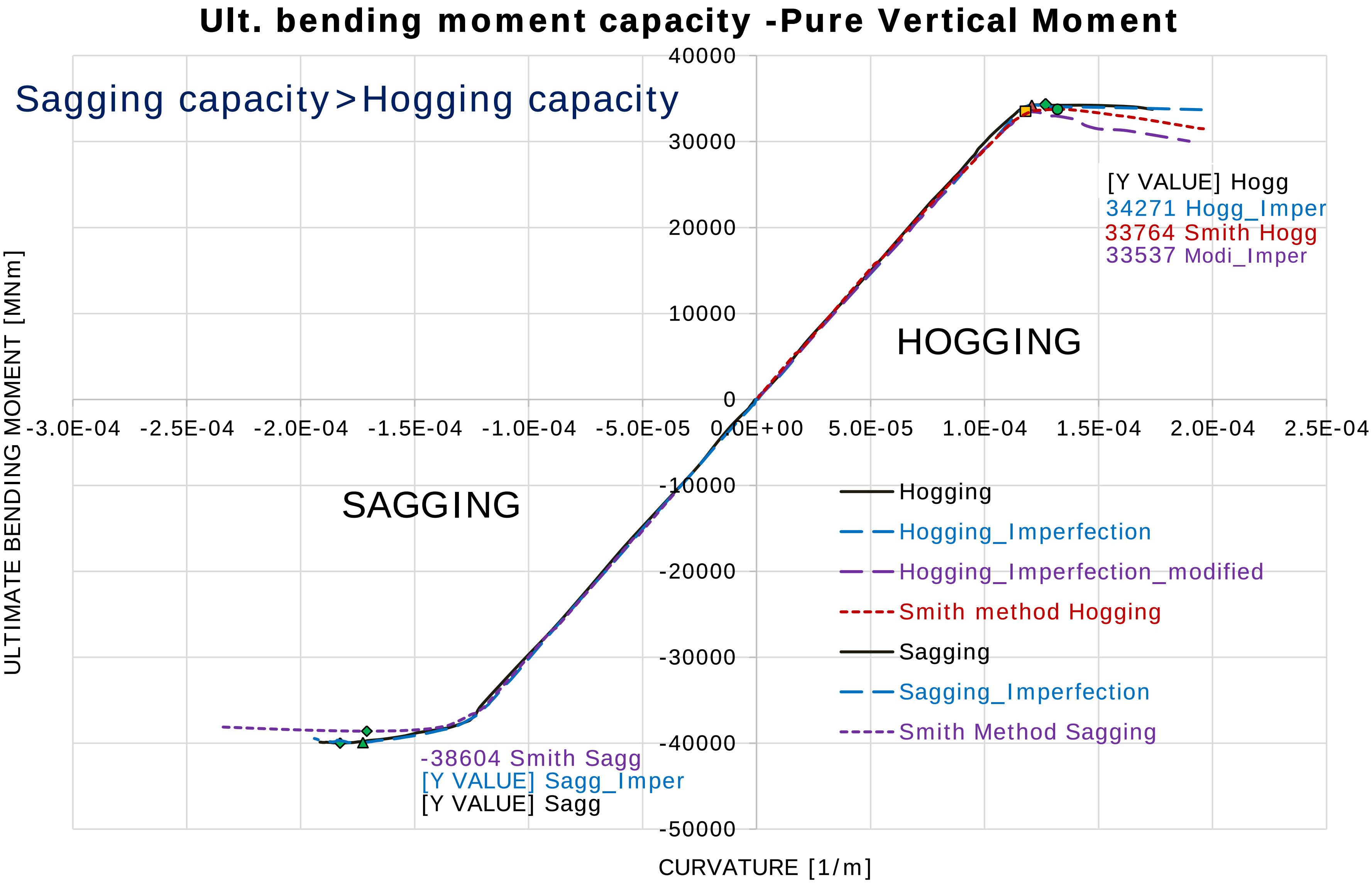
Cargo hold model – Boundary condition and analysis



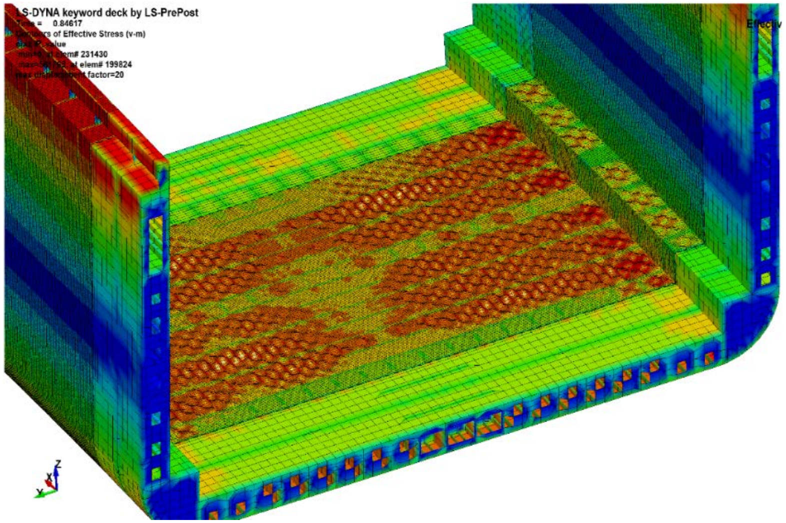
Nonlinear analysis is solved implicitly using BFGS method in LS-DYNA

Results of cargo hold analysis

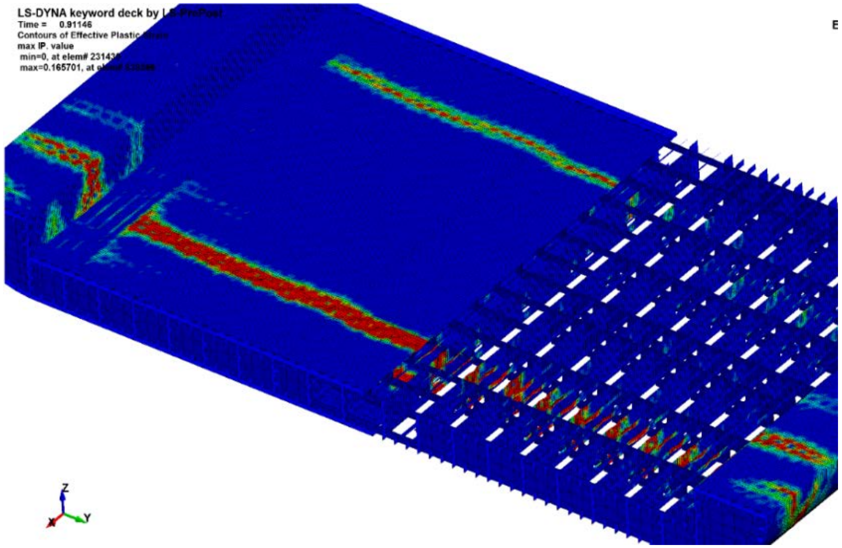
Sagging capacity>Hogging capacity



Results under hogging (without imperfection model)



vonMises @M=33228MNm
Scale factor= 20
Deflection follows modeled imperfection

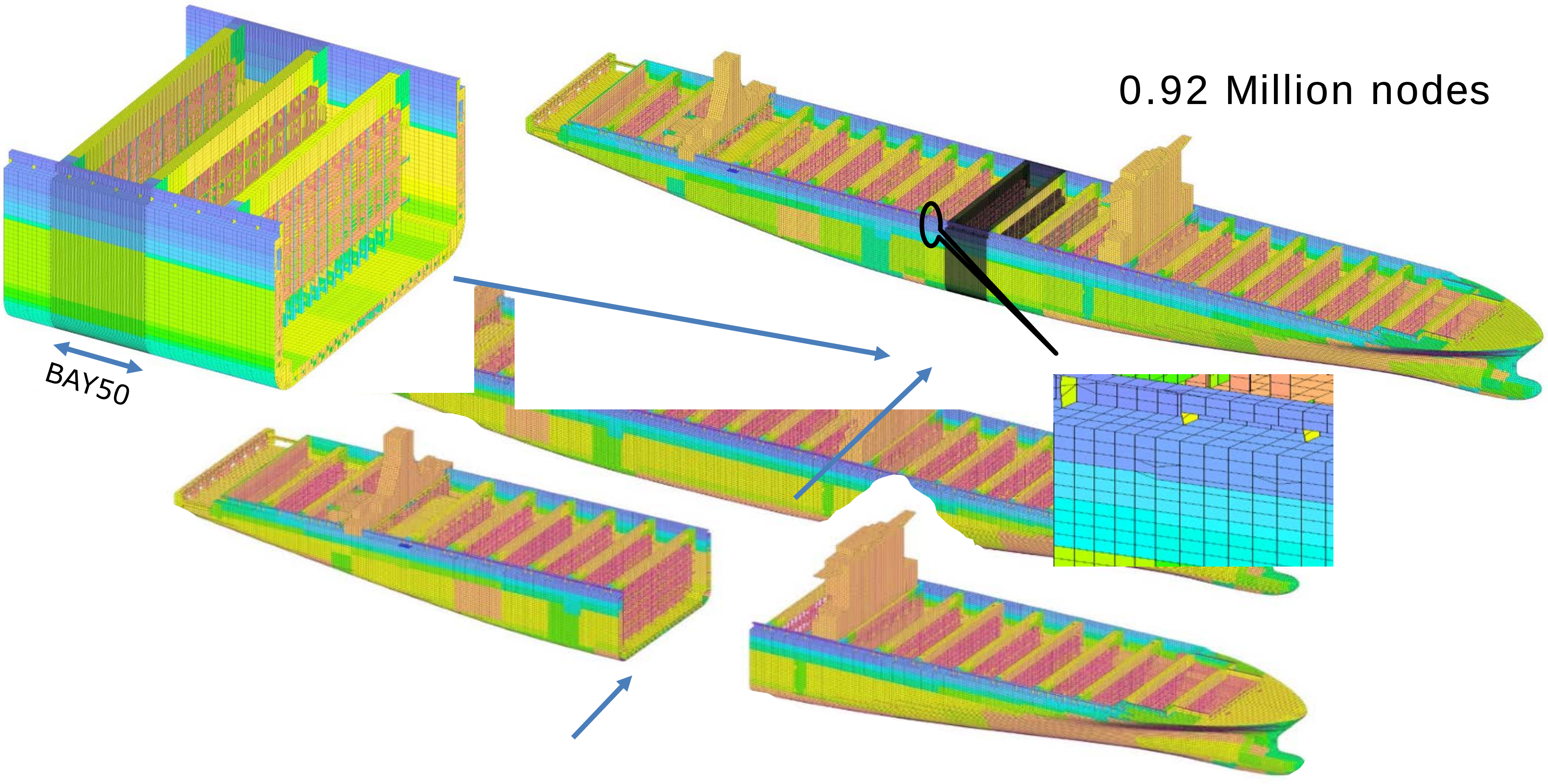


Plastic strain propagation Mu
Scale Factor=1

$$\frac{M_{u-hogg}}{\gamma_M * \gamma_{DB}} = \frac{33764}{1.1 * 1.1} = 27904\ MNm$$

- Hogging condition is critical.
- Smith method with safety factor 20% conservative.

Preparation of global FE model



Mesh size of ~800 mm

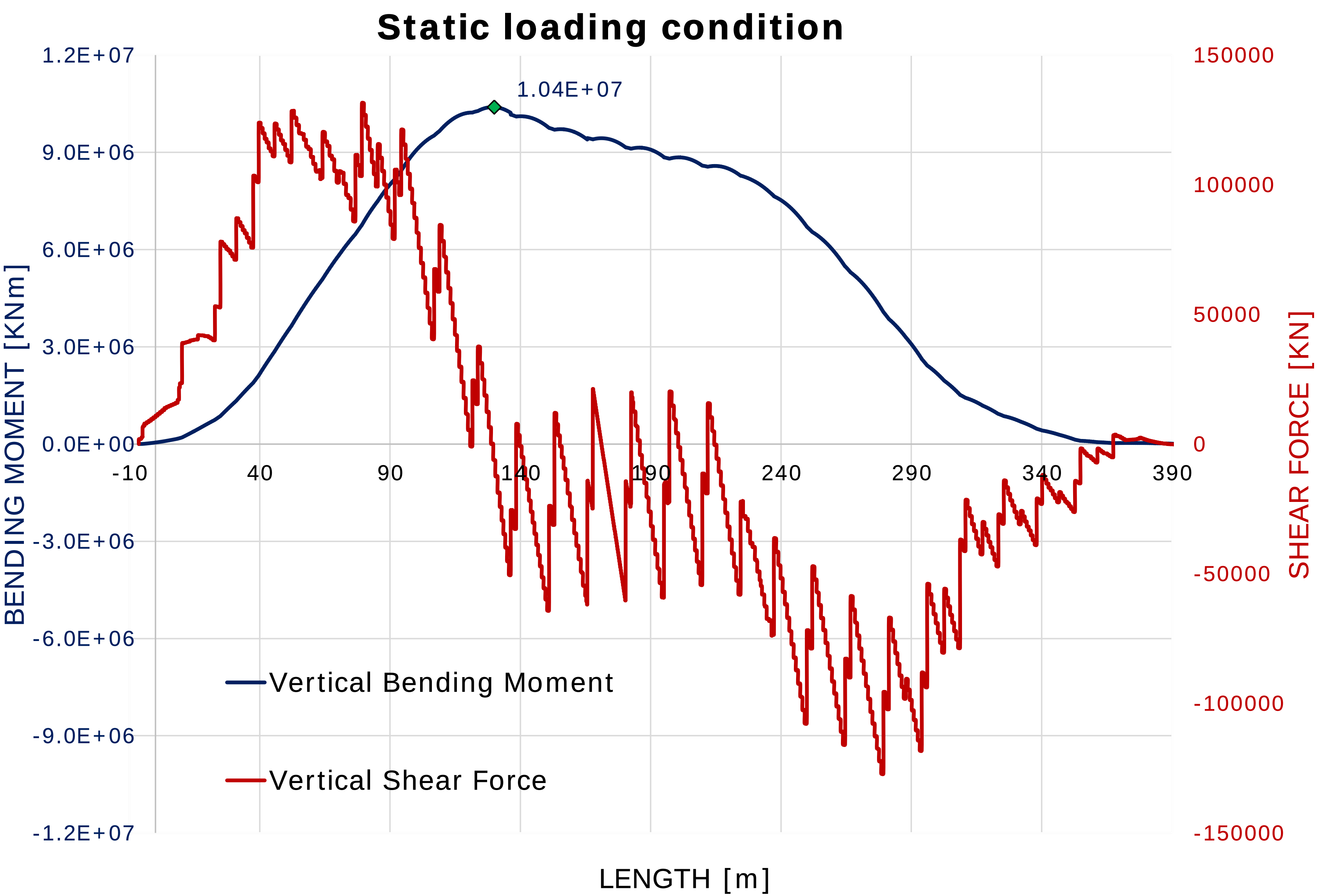
Loading generation for Global FE analysis

- GL Shipload software for load generation.
- Static loading condition – Still water loadings
  - 90% of Max. permisible stillwater BM - 1.04xE7 KNm [UR S11 A]
  - Draft - 14.5 m

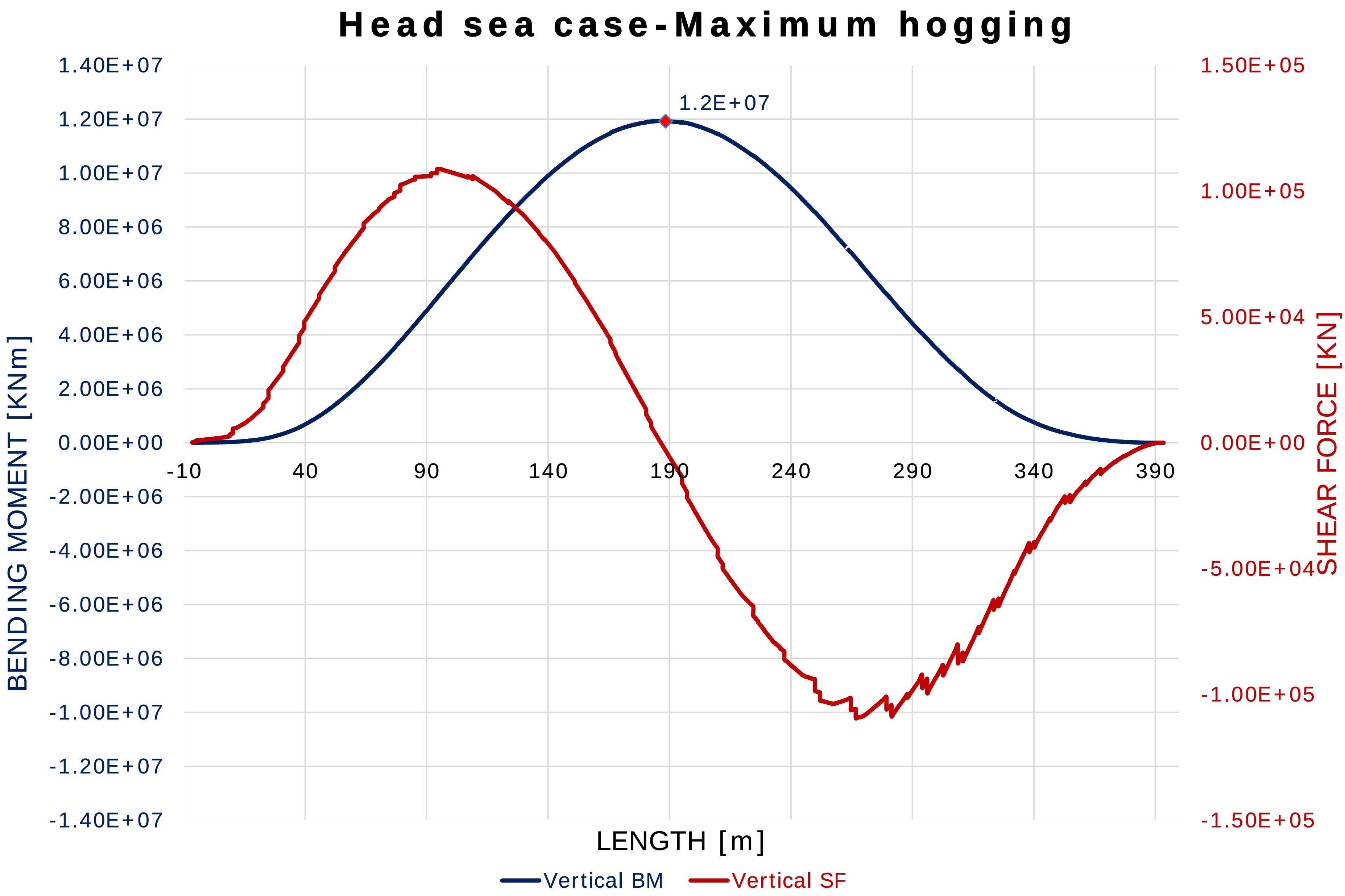
Analysed area Cargo hold 6	
Container loadings	4580 Tonnes/Bay
Bottom balast tanks	60% Fill rate
Side balast tanks	20% Fill rate

- Dynamic loadings - Waves loadings

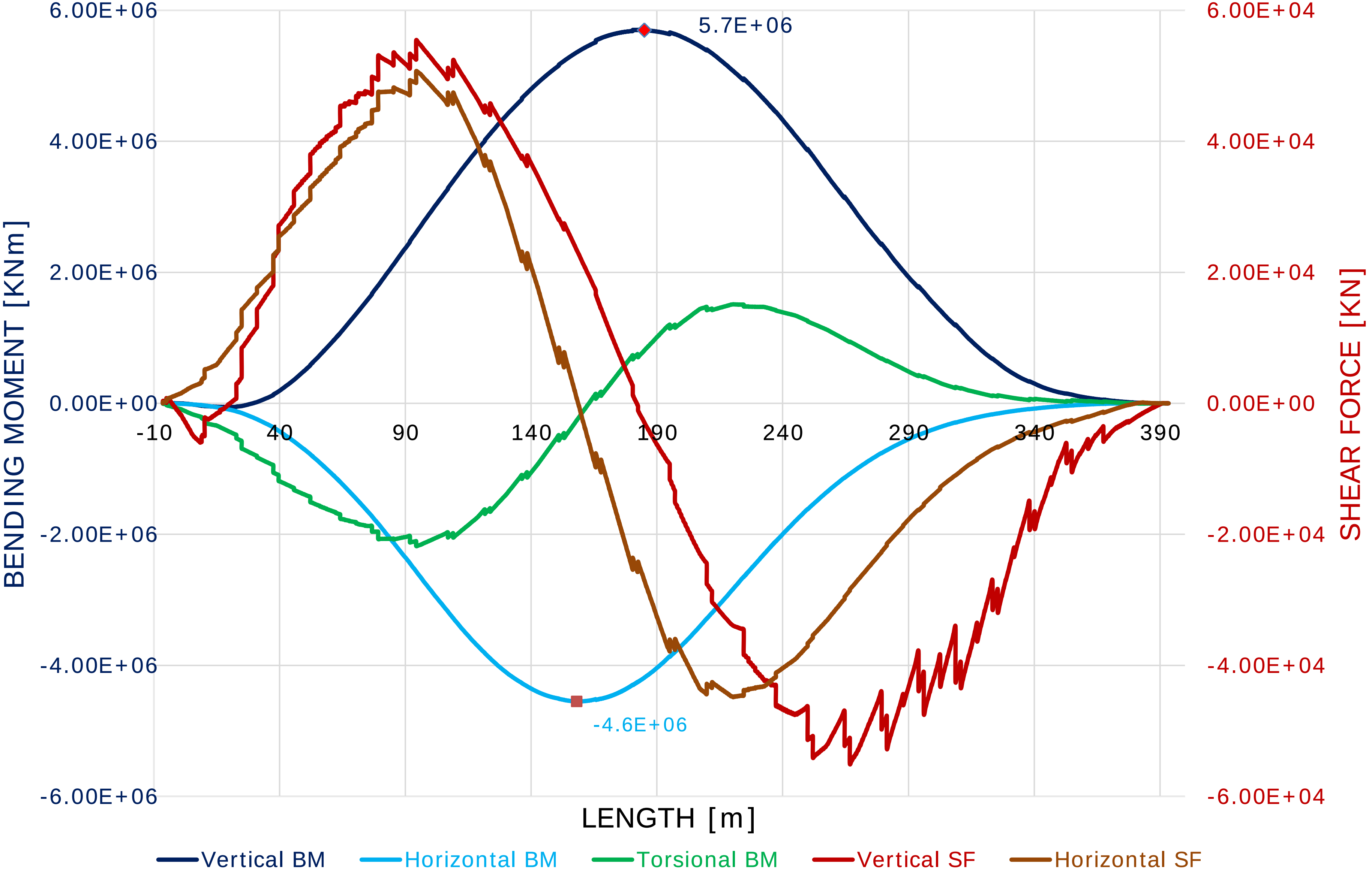
Dynamic Loading Cases	Wave Amplitude [m]	Wave Direction	Ship Velocity [Knots]
Head Sea	6.5	180°	5
Oblique Sea	4.7	120°	5



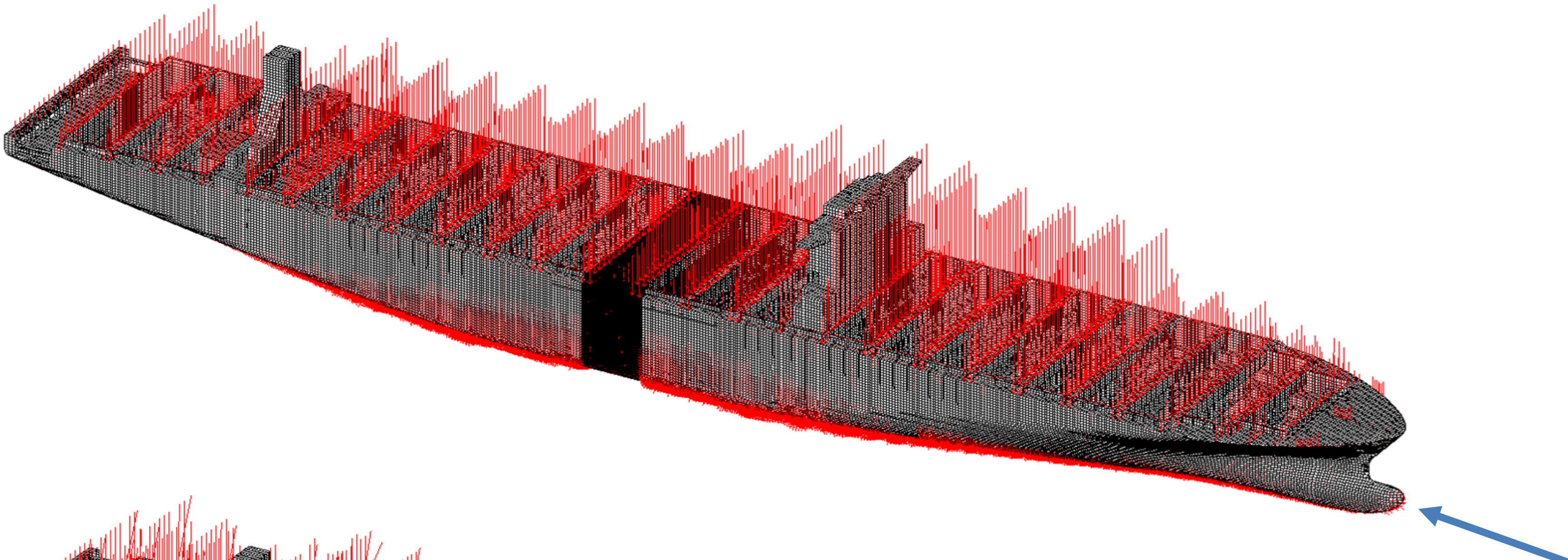
Static loading condition
1.2E+07
9.0E+06
6.0E+06
3.0E+06
0.0E+00
-3.0E+06
-6.0E+06
-9.0E+06
-1.2E+07
BENDING MOMENT [KNm]
150000
100000
50000
0
-50000
-100000
-150000
SHEAR FORCE [KN]
-10
40
90
140
190
240
290
340
390
LENGTH [m]
1.04E+07
Vertical Bending Moment
Vertical Shear Force


Head sea case-Maximum hogging
1.2E+07
BENDING MOMENT [KNm]
1.40E+07
1.20E+07
1.00E+07
8.00E+06
6.00E+06
4.00E+06
2.00E+06
0.00E+00
-2.00E+06
-4.00E+06
-6.00E+06
-8.00E+06
-1.00E+07
-1.20E+07
-1.40E+07
SHEAR FORCE [KN]
1.50E+05
1.00E+05
5.00E+04
0.00E+00
-5.00E+04
-1.00E+05
-1.50E+05
-10
40
90
140
190
240
290
340
390
LENGTH [m]
Vertical BM
Vertical SF

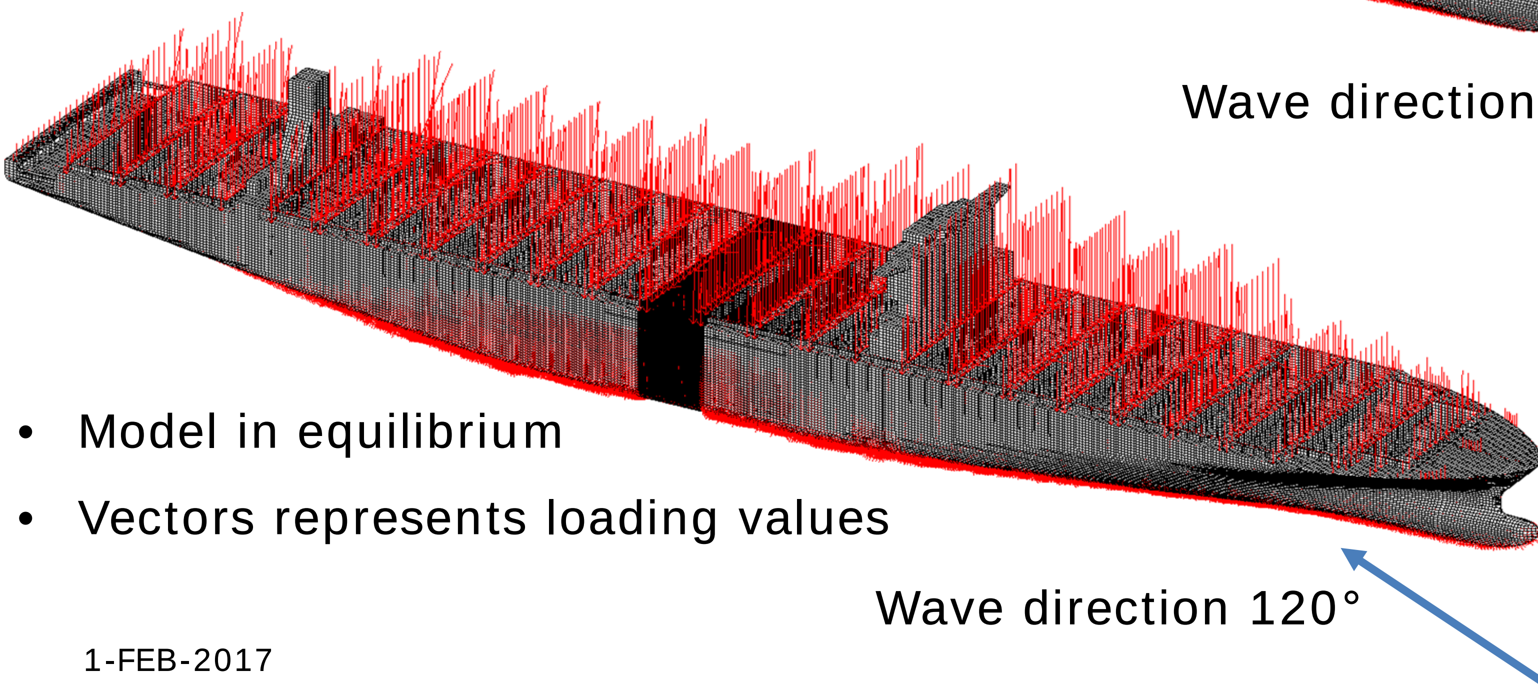
Oblique sea case- Combined loads



Nodal loads on global FE model



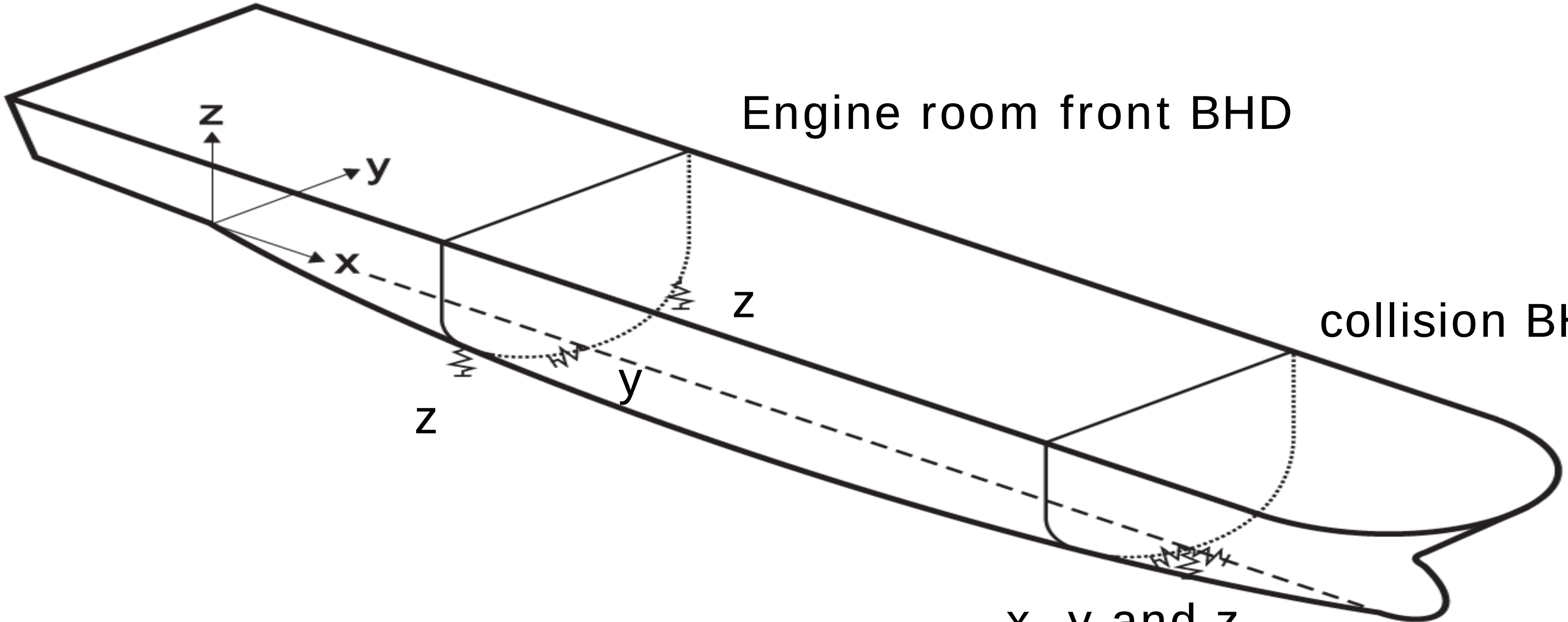
Wave direction 180°



- Model in equilibrium
- Vectors represents loading values

Wave direction 120°

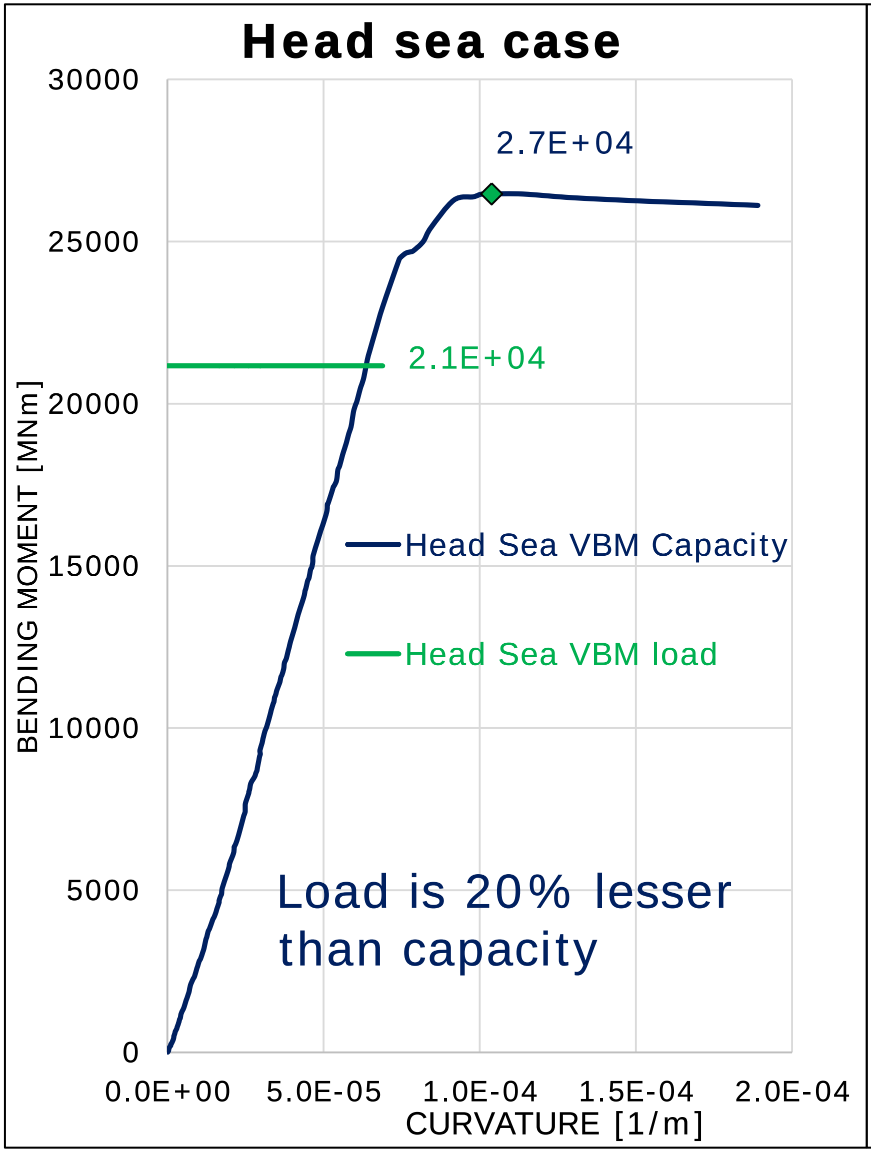
Boundary conditions - Global analysis

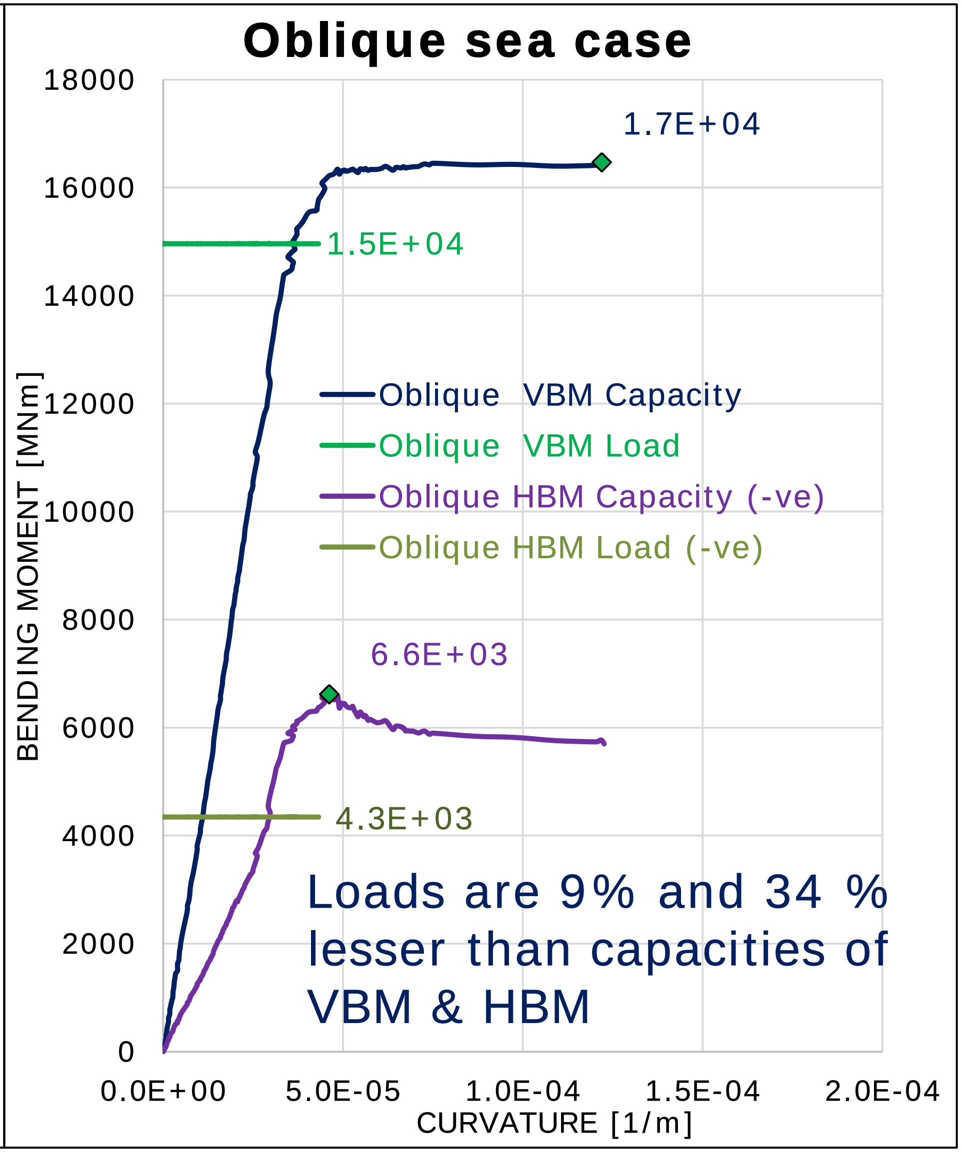


Nonlinear analysis is solved implicitly using BFGS method in LS-DYNA

Reference:
DNV GL Class giudelines, Finite Element Analysis.

Results of global FE analysis-Ult. bending moment





Conclusion

- Hogging condition is critical in container vessels.
- Smith method provides conservative results for pure VBM.
- Designed container ship is safe under combined loading conditions.