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Effect of mooring line type on mooring safety of Ultra Large Container Ships

Open

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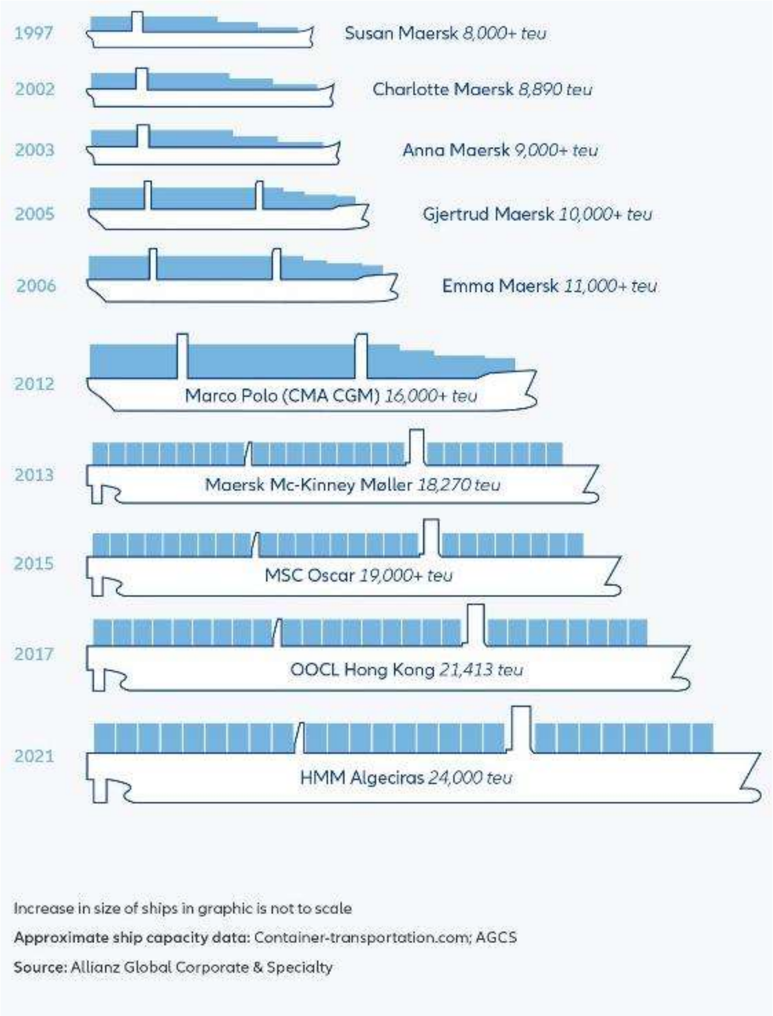
27 August 2024

Why study the behaviour of moored ships in ports?

- To provide insight in the dynamic behaviour
  - Increase safety
  - Improve efficiency
  - Reduce investments

Why for large container ships?

- Ships have grown significantly in size, especially container ships
  - Large wind areas > more wind loading
  - Large vertical line angles
  - Increase of line and bollard forces
  - More challenging to ensure safe mooring



400 m container ships

Emma Maersk-2006-15,500 TEU

Barzan-2015-19,870 TEU

MOL Triumph-2017-20,146 TEU

HMM Algeciras-2020-24,000

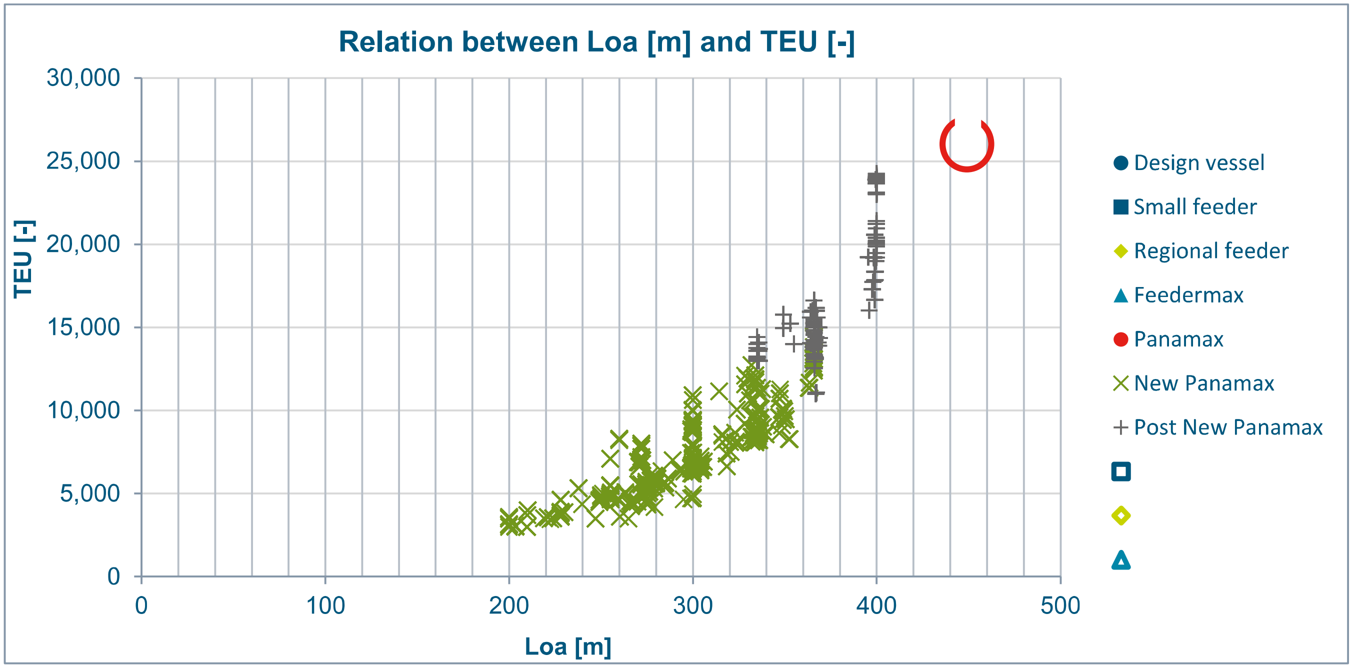
Largest since 2020: 24,000 TEU!

- HMM Algeciras class
- Evergreen A-class (top photo)
- MSC Irina class (most TEU)
- OOCL Spain
- ONE Innovation (bottom photo)

- List of largest container ships - Wikipedia

Future container ships?

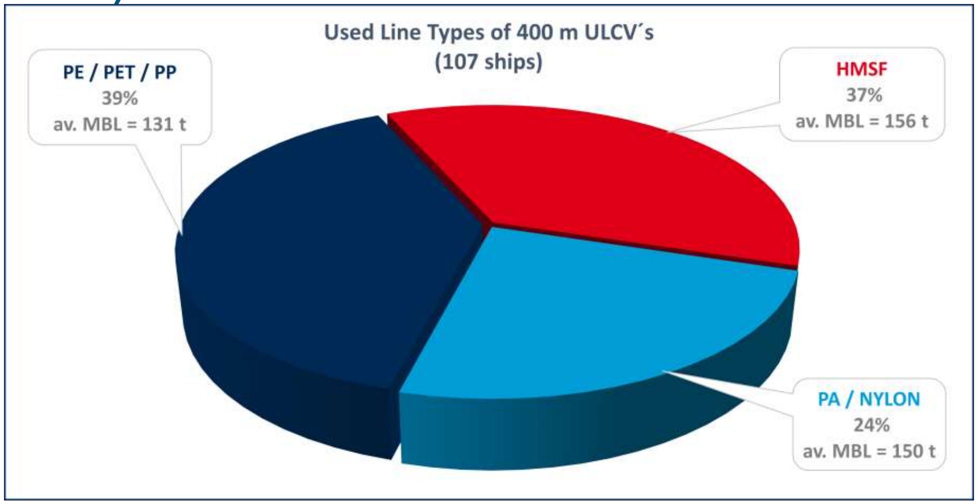
- Maximum length currently: 400m
- TEU has increased to 24,000 TEU
- Future size: >450m, >26,000 TEU?



Safe mooring of large container ships

- Post/New-Panamax >350 m, up to future vessels of 450 m
- Improve the mooring given the wind climate in the port
- Possible measures to improve the mooring:

1. **Winch management (400m; 20,000TEU ULCS)**
2. **Effect mooring line material (450m; 26,000 TEU ULCS)**



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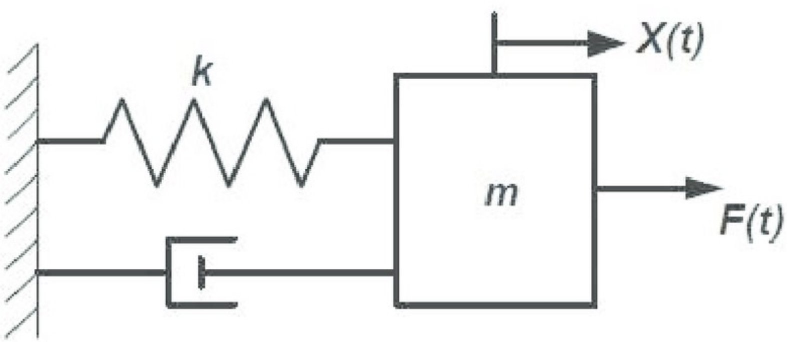
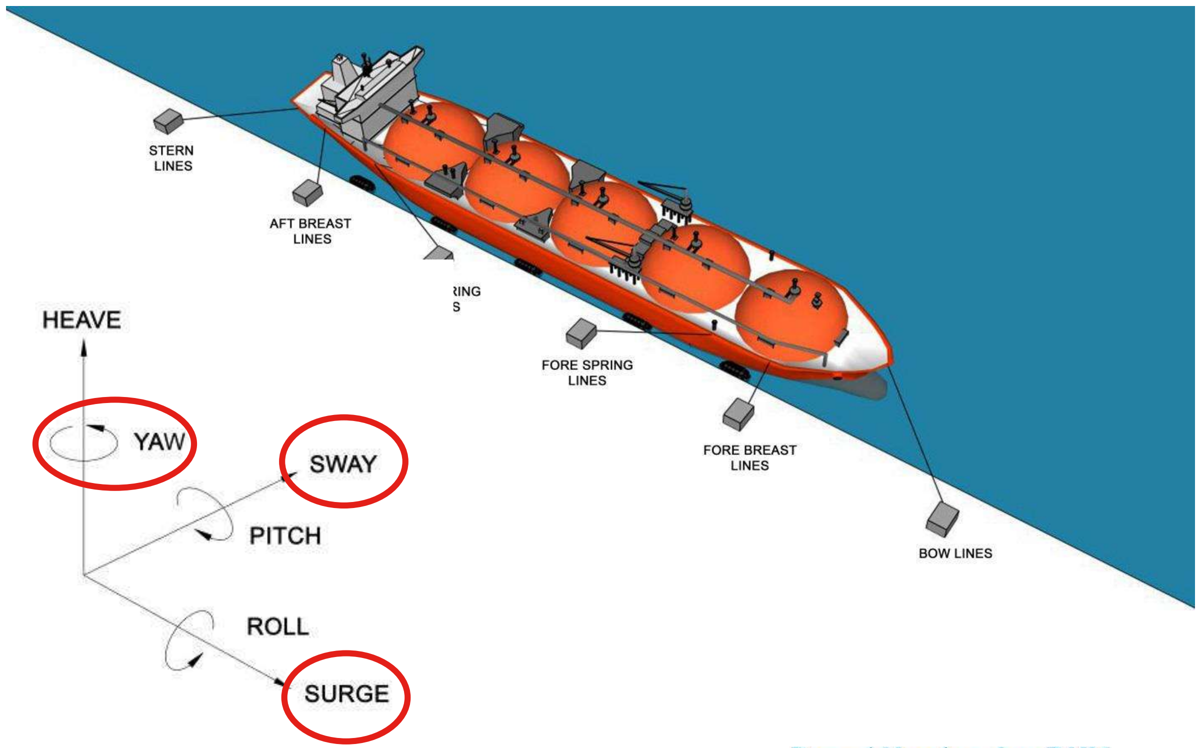
What is a Dynamic Mooring Analysis (DMA)?

- Computer modelling of moored ship behaviour in time-varying (i.e. gusting) wind
- Moored ship in wind = forced mass-spring system in 3 degrees of freedom
  - Force = wind
  - Ship = mass
  - Spring = lines & fenders





Used software

- **Diffrac and aNySIM by Marin**
  - In Diffrac:
    - Wave diffraction
    - Proximity of quay and seabed
  - In aNySIM:
    - mooring points, lines and fenders
    - additional viscous damping

MARIN

BETTER SHIPS, BLUE OCEANS

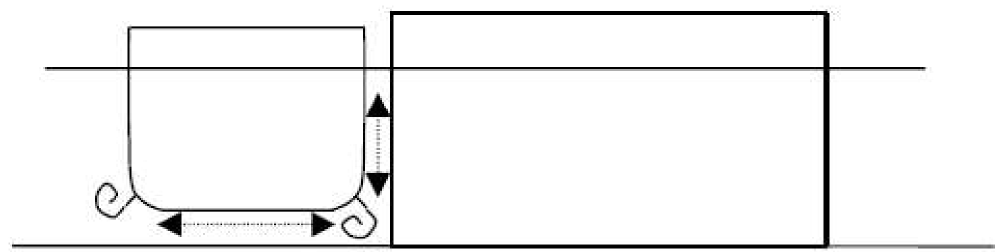
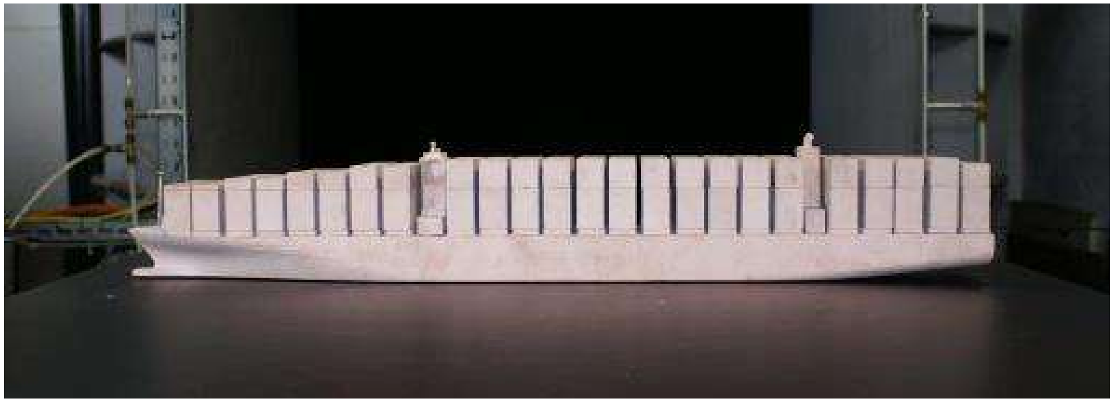


Fig. 2. Illustration of damping effects

Drag coefficients

- Based on Test Report on Wind Tunnel Studies, Hamburg Port Authority (2015 & 2020)
- Globe: Superstructure fore and aft
  - 13 tiers, fully loaded
  - Coefficients for surge, sway and yaw
- Effect port surroundings on wind force not included



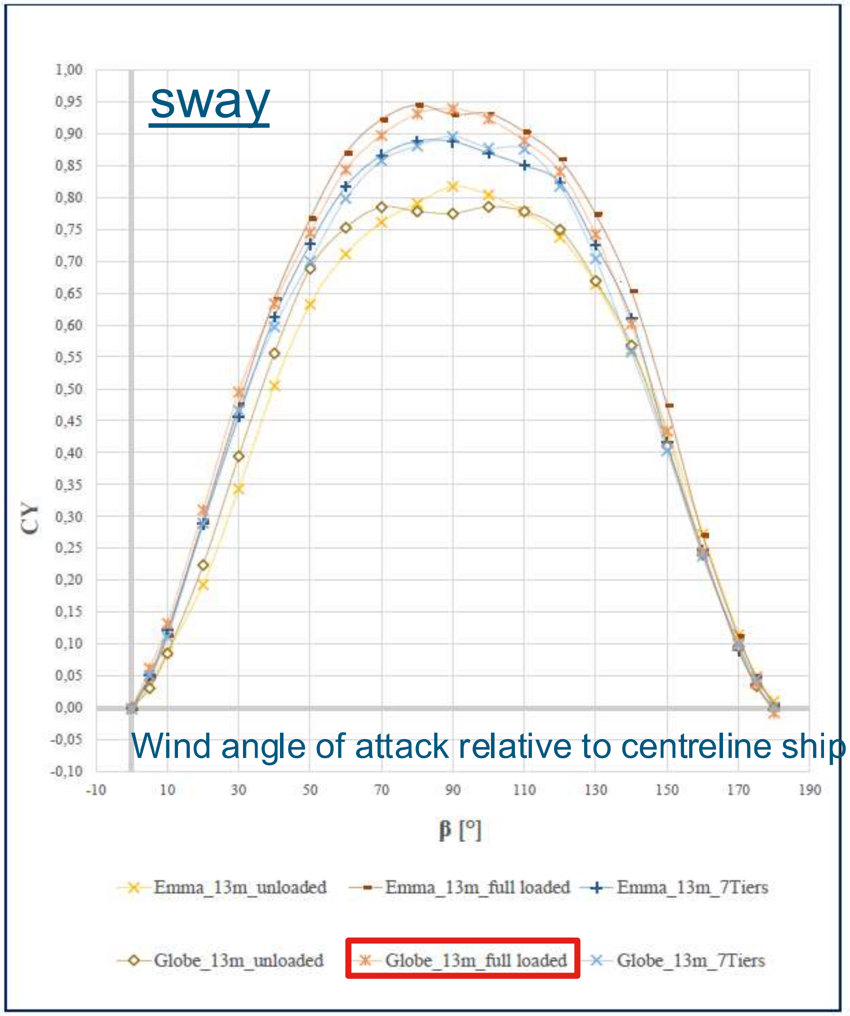
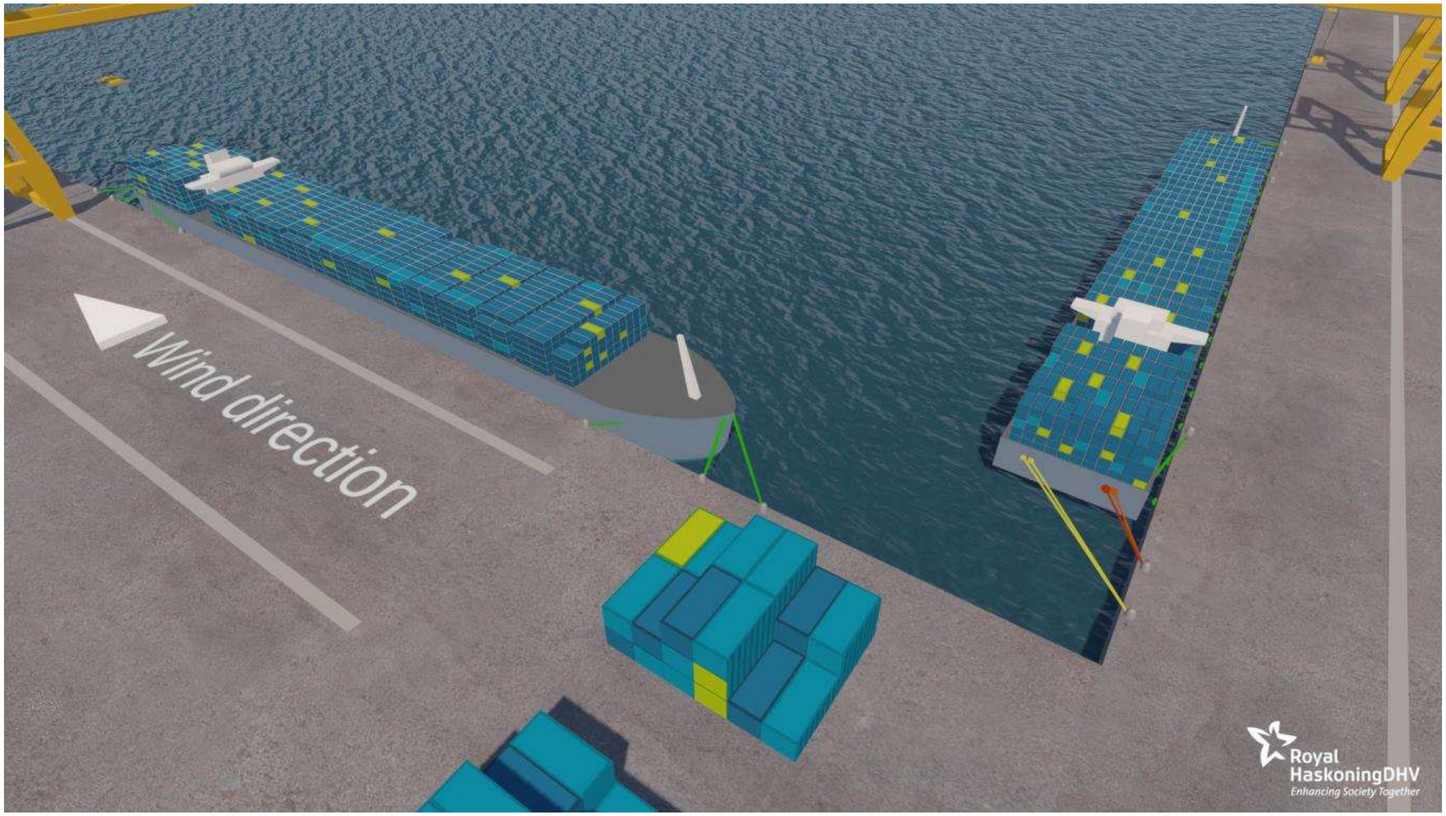


Illustration dynamic response

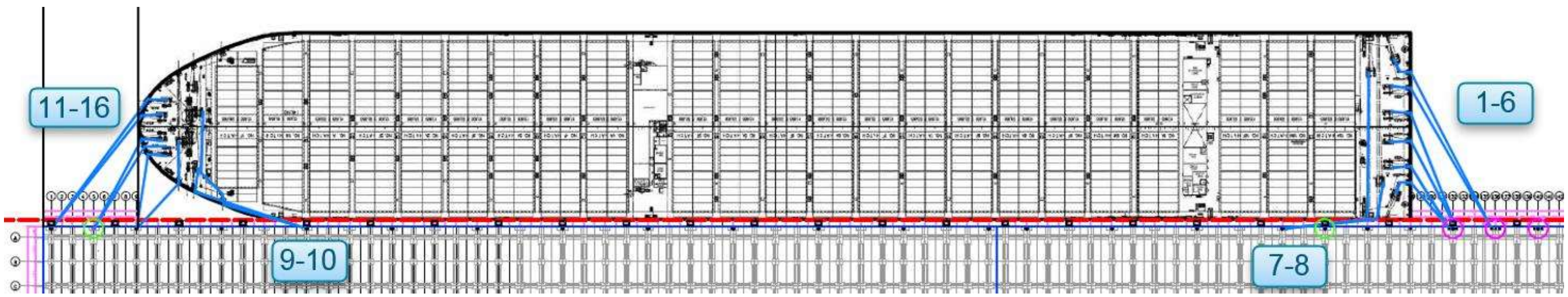
- Oscillatory motion response
- Peak loads in mooring lines
- Fender compressions in off-quay wind



1 Comparison winch management

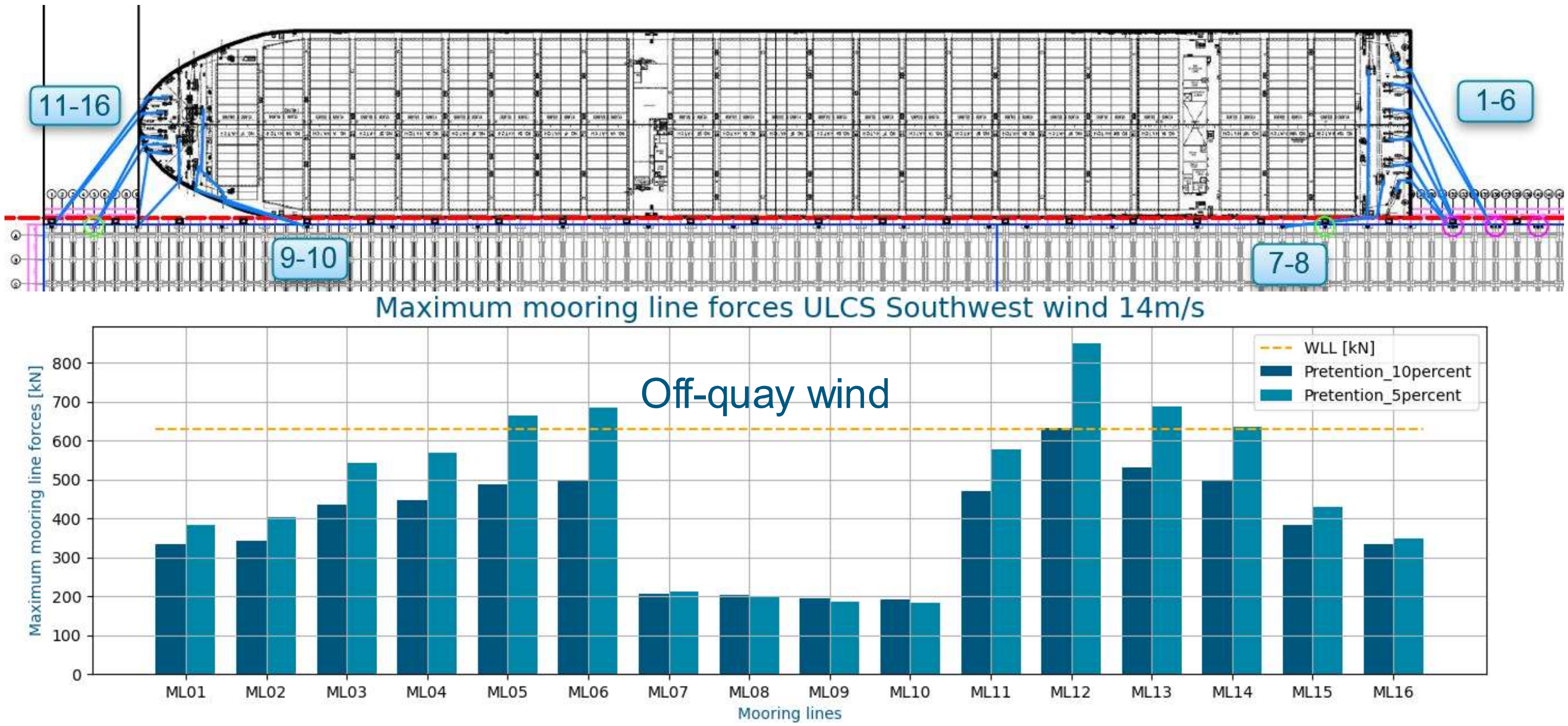
- Winch management is important in ensuring vessels are kept safely moored
- Increasing pretension when adverse conditions are expected can keep winches from rendering and lines from snapping

- Example for Post New Panamax: 400m / 20,000 TEU
- In modelling: pretension 5 and 10% of Minimum Breaking Load



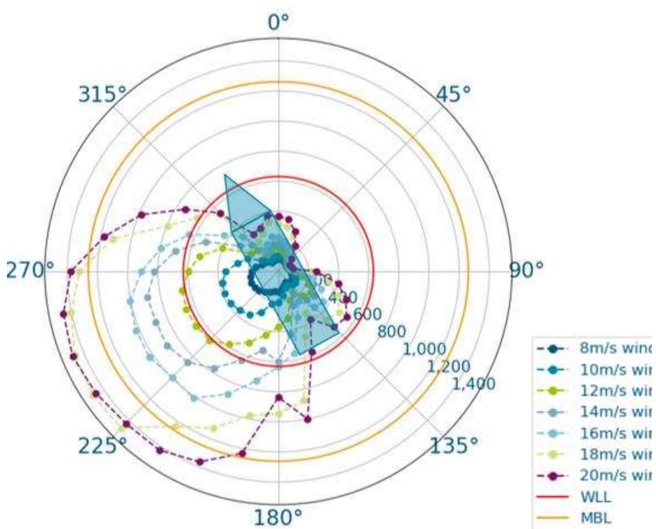
1 Comparison winch management

- Maximum mooring line force in simulation
- More pretension = stiffer mooring = less motion response in time-varying wind

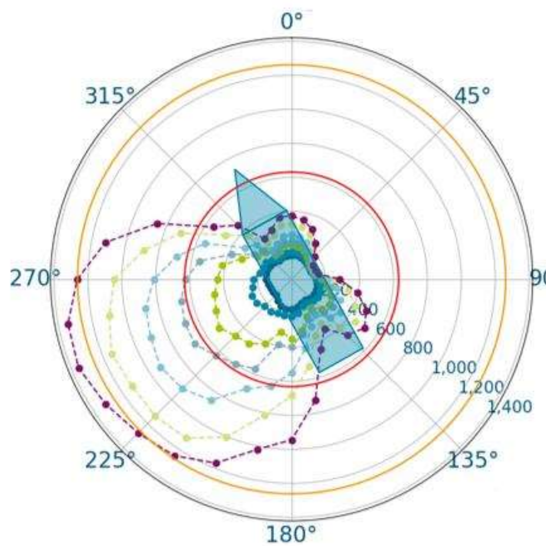


1 Comparison winch management

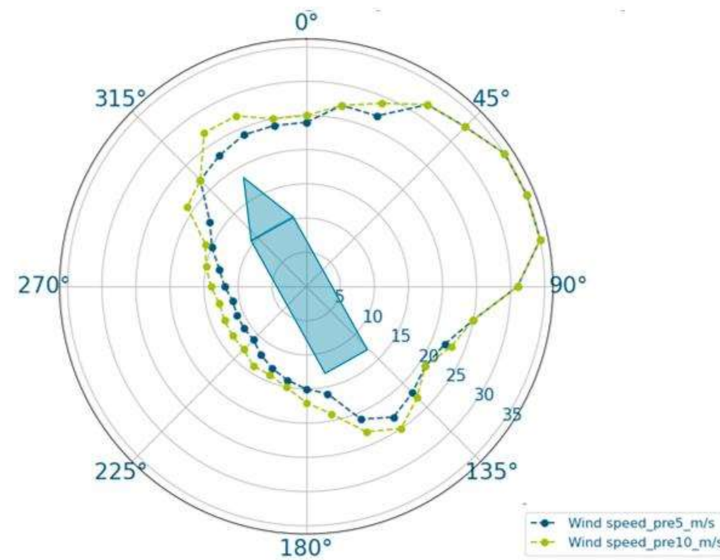
- Polar plots max Fline => limiting wind speed plot



Max. mooring line force (kN)
with pre-tension 5%



Max. mooring line force (kN)
with pre-tension 10%



Limiting wind speed
for safe mooring (m/s)

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2 Effect mooring line material

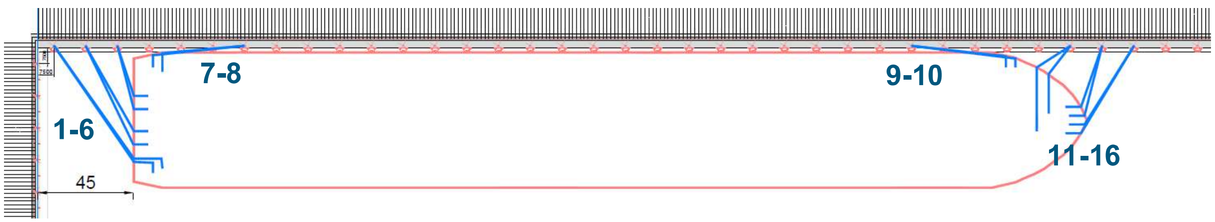
- Future 450m (≥26,000 TEU) Ultra Large Container Ship (ULCS)

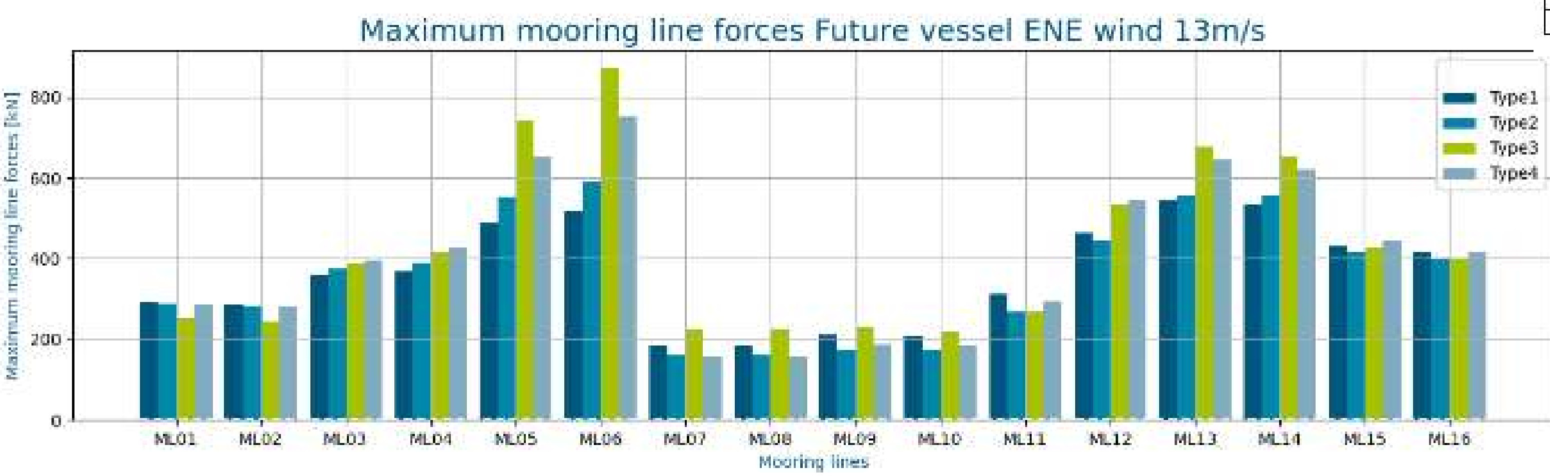
Table 1 Main particulars ship used in analysis

Parameter	Future vessel Post New Panamax
Cargo capacity TEU	≥26,000
Length over all L_{oa}	450m
Length between perpendiculars L_{pp}	427.5m
Beam B	63.3m
Depth D	30.0m
Draught T	15.5m
Displacement Δ	~345,000t
Transverse windage area A_s	19,295m²
Longitudinal wind area A_L	2,883m²

Table 2 Particulars analysed mooring lines

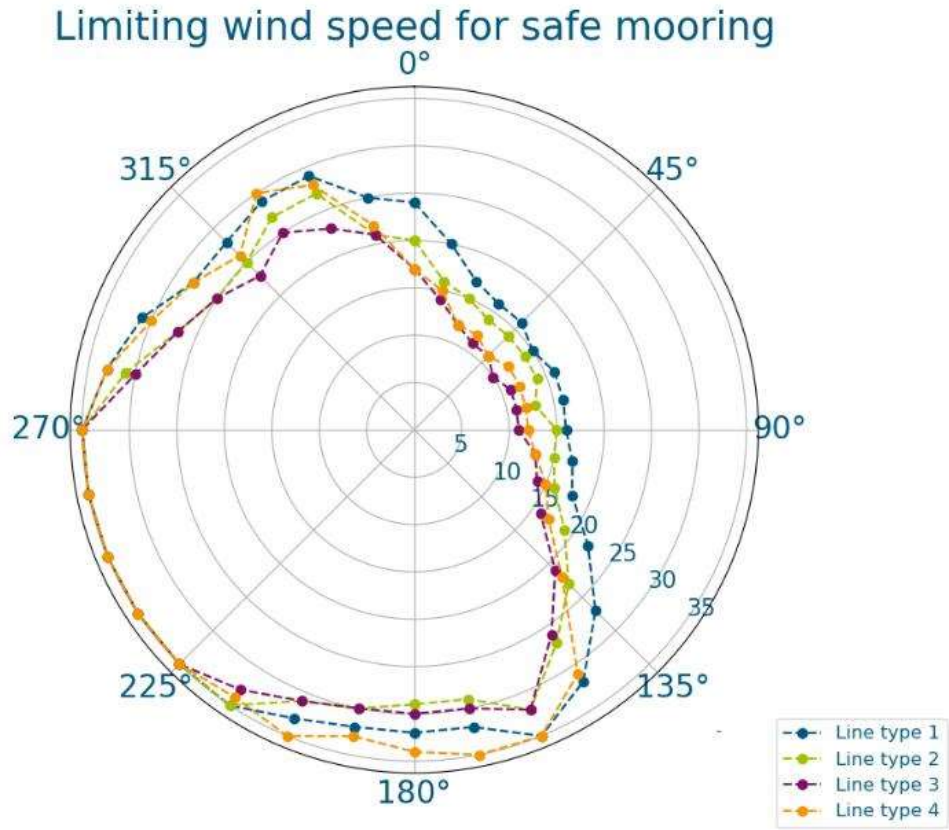
Parameter	Type 1	Type 2	Type 3	Type 4
No. of line	16	16	16	16
Material	HMPE	HMPE	PE	Nylon
MBL (t)	230	160	130	130
WLL (t)	115	80	65	65
Tail			No tail	No tail
Material	Nylon	Nylon		
Length (m)	11	11		
MBL (t)	310.5	220		





2 Effect mooring line material

- Limiting wind speeds
  - For stiffest lines governed by bollard forces
    - capacity: 150t



2 Effect mooring line material

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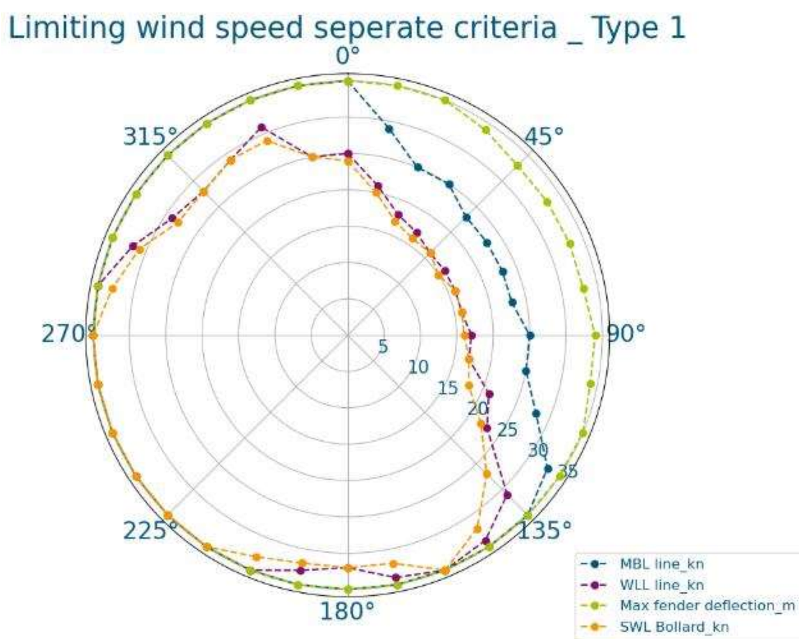

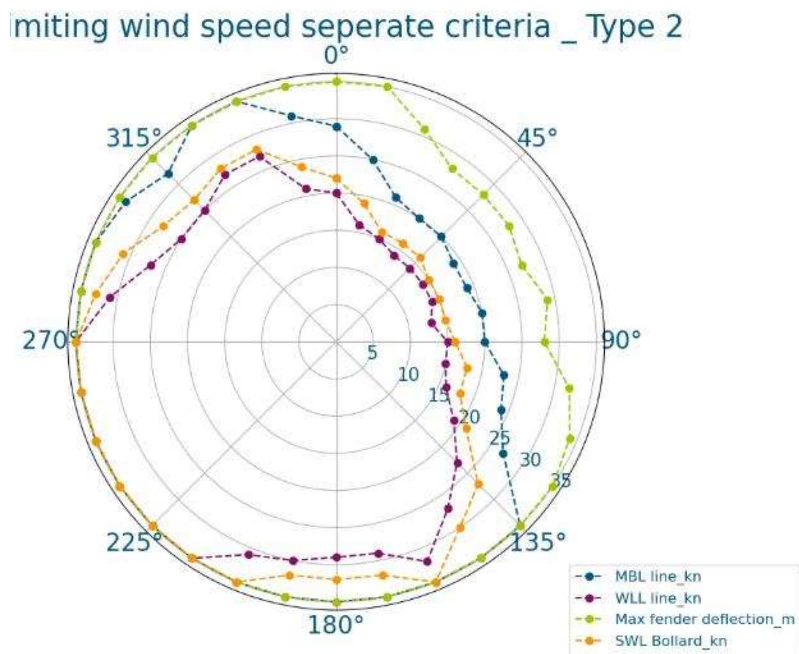

Conclusion

- Use: DMA to understand the moored ship behaviour in ports
- Purpose: improve & safer mooring whilst enable higher throughputs in ports.

- Several possibilities to improve the mooring of large container ships in wind are:
  - Winch management (pretension)
  - Line make-up & material

- But also:
  - Mooring force predictions
  - Crossed mooring arrangement
  - Tug assistance
  - ShoreTension®
  - Dynamoor (Trelleborg)

Thank you for your attention.

Questions?

Smart Mooring

- Response predictions based on wind forecasts: [Smart Mooring | Royal HaskoningDHV]

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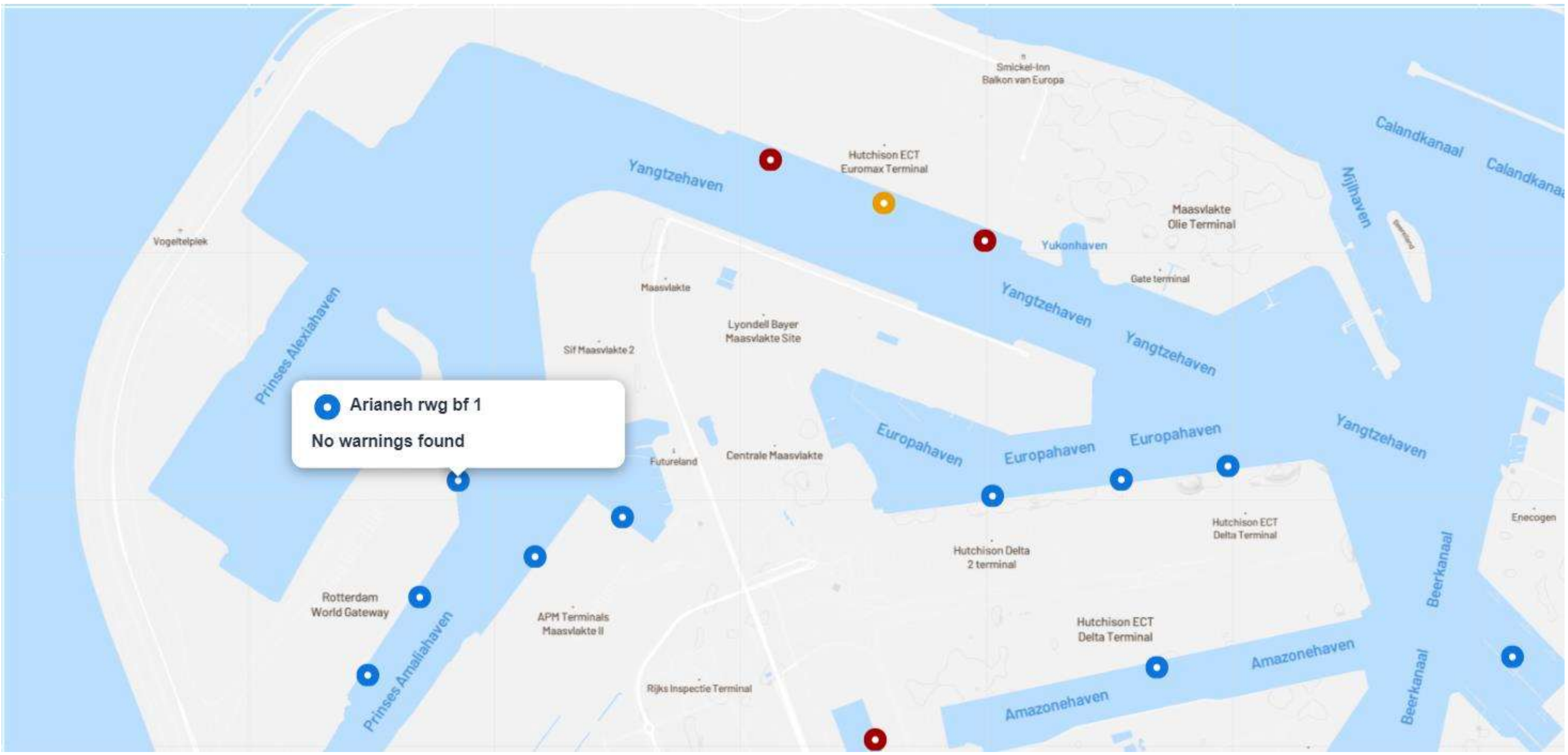
No issue



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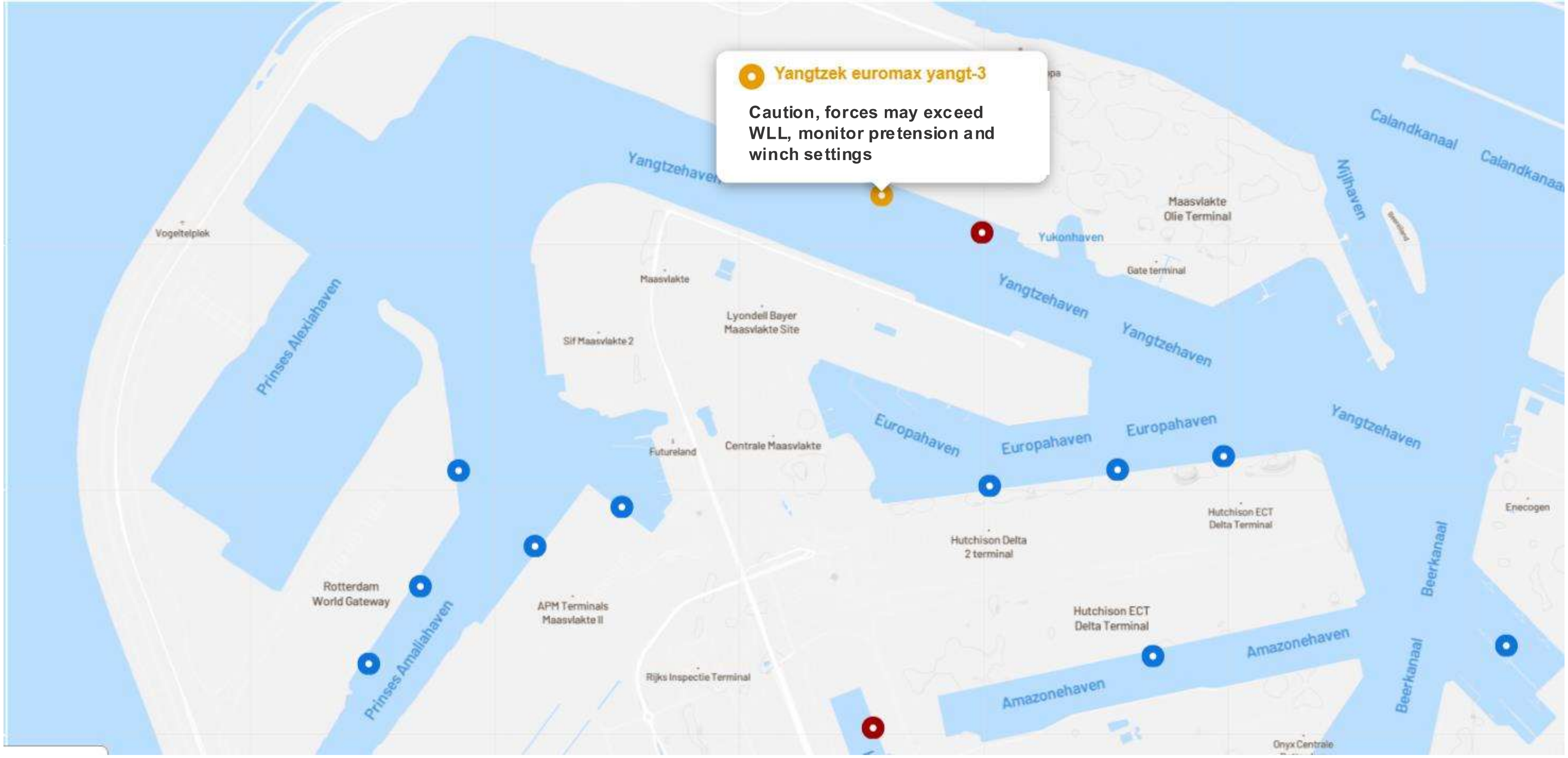
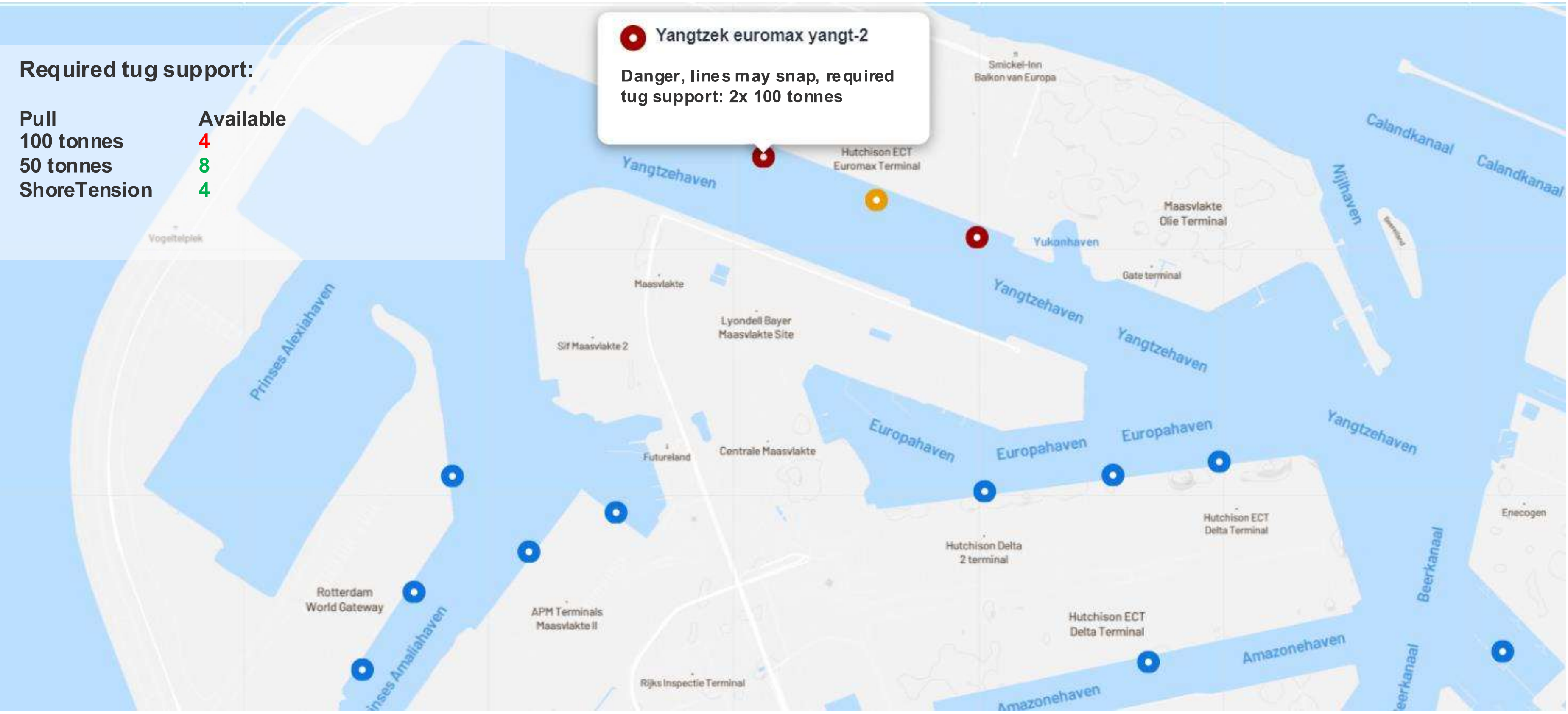


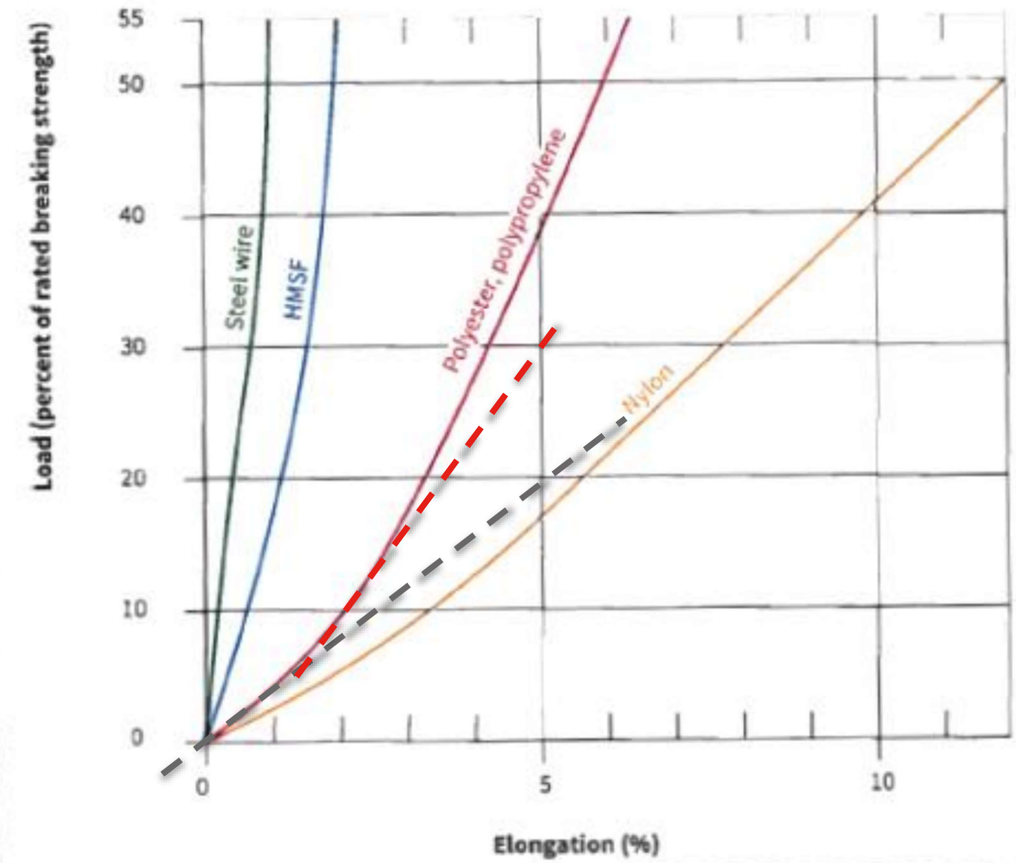
Yangtzek euromax yangt-3
Caution, forces may exceed WLL, monitor pretension and winch settings
Yangtzehaven
Yukonhaven
Maasvlakte Olie Terminal
Gate terminal
Calandkanaal
Calandkanaal
Nijlhaven
Vogeltelplek
Maasvlakte
Lyondell Bayer Maasvlakte Site
Sif Maasvlakte 2
Prinses Alexiahaven
Europahaven
Europahaven
Europahaven
Futureland
Centrale Maasvlakte
Hutchison ECT Delta Terminal
Enecogen
Hutchison Delta 2 terminal
Beerkanaal
Rotterdam World Gateway
APM Terminals Maasvlakte II
Prinses Amaliahaven
Hutchison ECT Delta Terminal
Amazonehaven
Amazonehaven
Rijks Inspectie Terminal
Onyx Centrale


Required tug support:
Pull Available
100 tonnes 4
50 tonnes 8
ShoreTension 4
Yangtzek euromax yangt-2
Danger, lines may snap, required tug support: 2x 100 tonnes
Yangtzehaven
Hutchison ECT Euromax Terminal
Yukonhaven
Maasvlakte Olie Terminal
Calandkanaal
Nijlhaven
Europahaven
Amazonehaven
Beerkanaal
Prinses Alexiahaven
Rotterdam World Gateway
APM Terminals Maasvlakte II
Hutchison Delta 2 terminal
Hutchison ECT Delta Terminal
Centrale Maasvlakte
Lyondell Bayer Maasvlakte Site
Futureland
Gate terminal
Enecogen

Mooring line stiffness

- Load-elongation
- From OCIMF MEG4

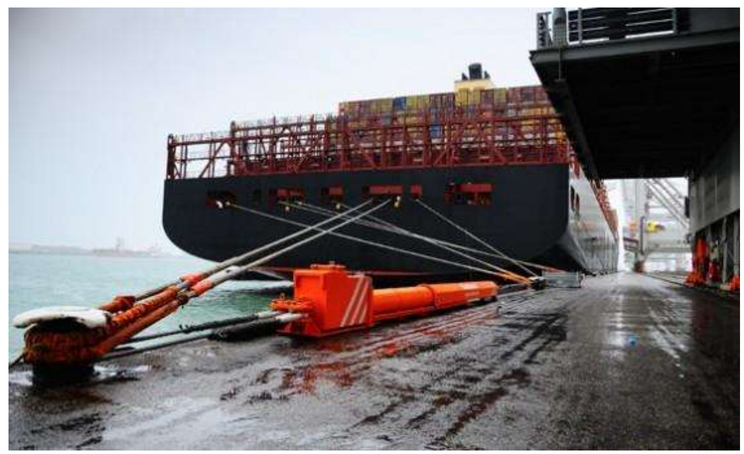
- Effect of mooring line material, MBL, length and pretension on mooring line stiffness



Safe mooring of large container ships

- >350 m, Post New-Panamax
- To improve the mooring given the wind climate in the port
- Possible measures to improve the mooring:

1. **Crossed mooring arrangement**
2. **Tug assistance**
3. **ShoreTension® mooring system**



Results are based on numerical modelling of the response of the moored container ships in time-varying (i.e. gusting) wind (Dynamic Mooring Analysis)

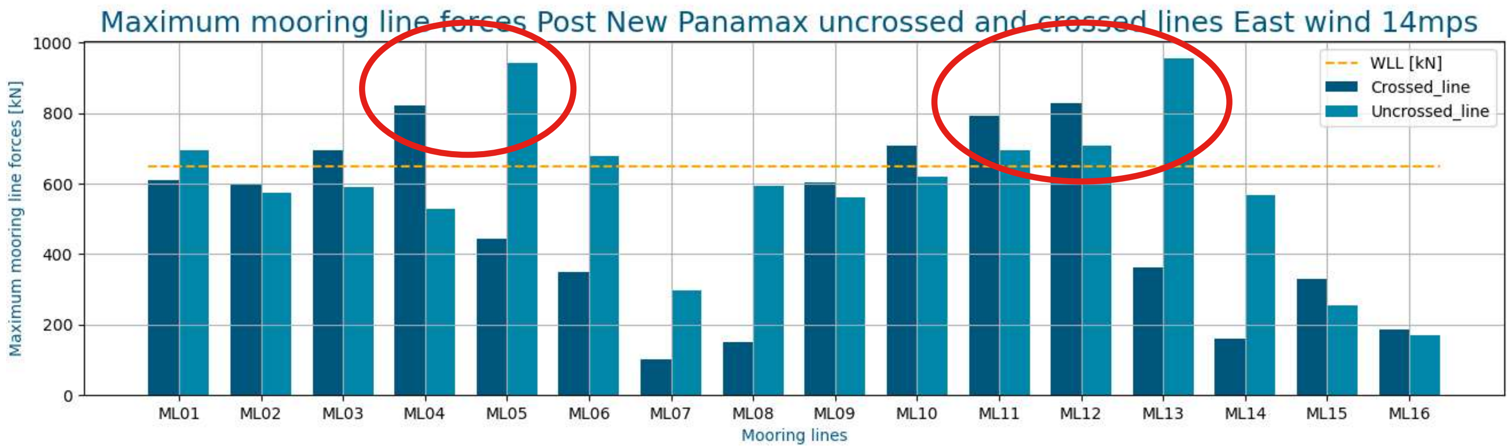
1 Crossed mooring

- Example for uncrossed and crossed mooring arrangement layout
- For Post New Panamax 369m / 15,000 TEU

Crossed (top) and Uncrossed (bottom) line layouts

1 Crossed mooring

- Example for uncrossed and crossed mooring arrangement layout for Post New Panamax



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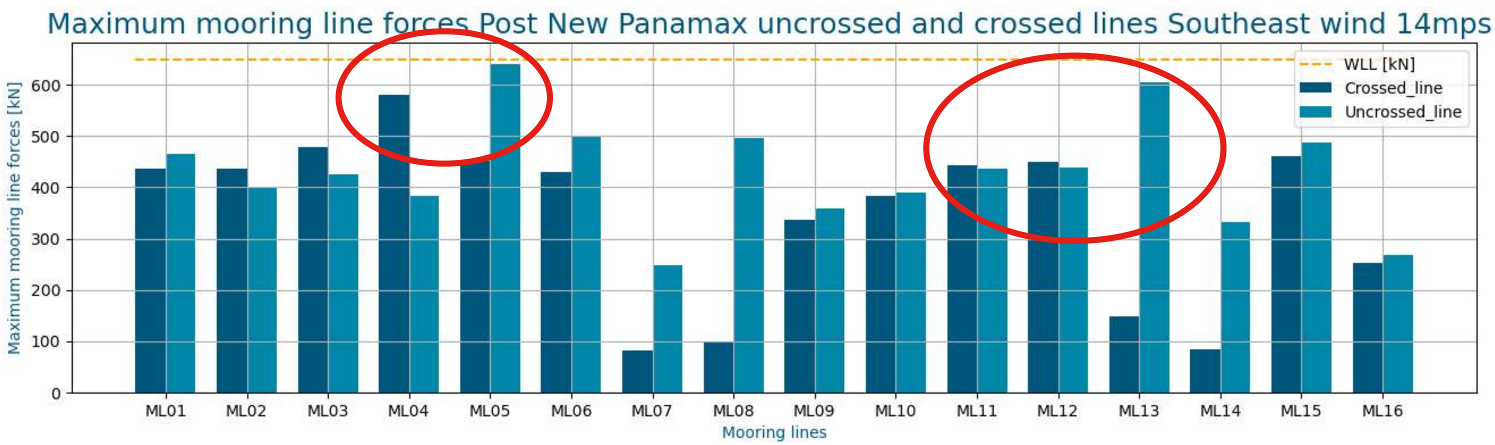
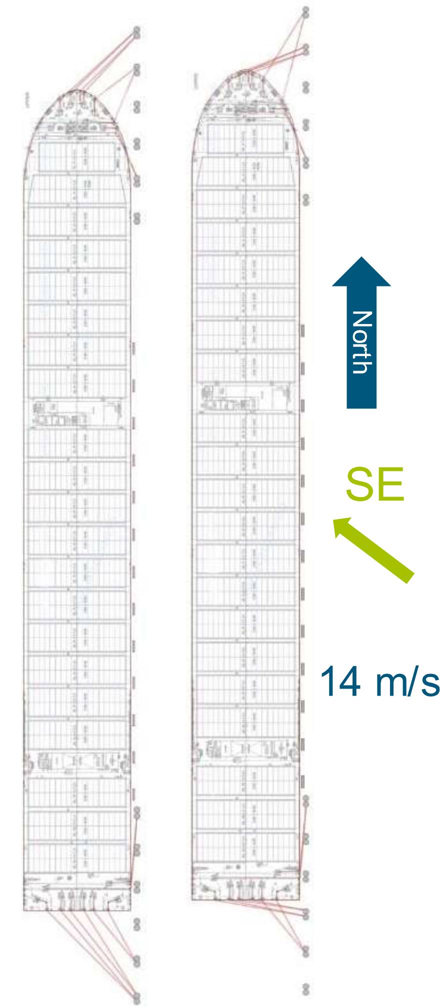
1 Crossed mooring

- Example for uncrossed and crossed mooring arrangement layout for Post New Panamax





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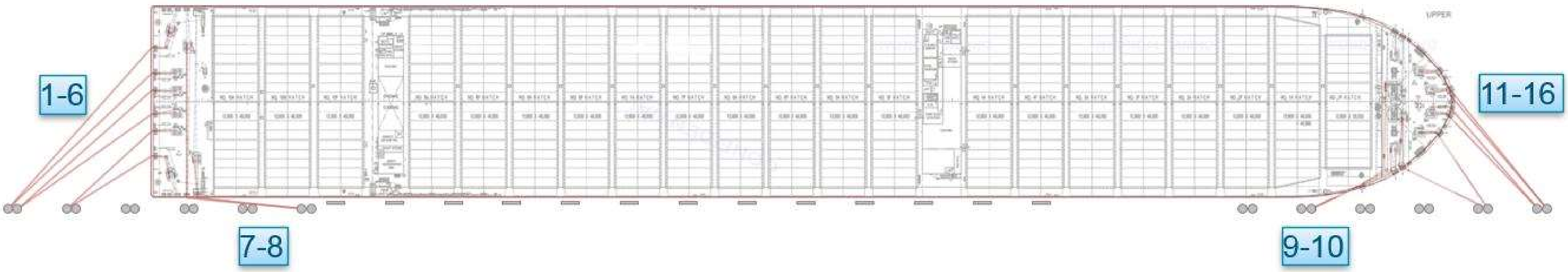
2 Effect of tug assistance

- Tugs pushing in the side often used in ports in adverse wind conditions
- Example for Post New Panamax: 369m / 15,000 TEU, with tug assistance



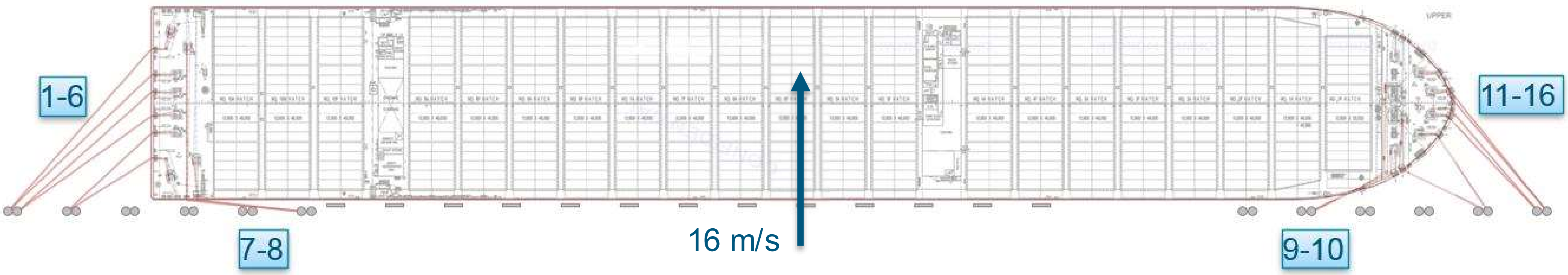
Transverse wind area: ~14,000 m^2

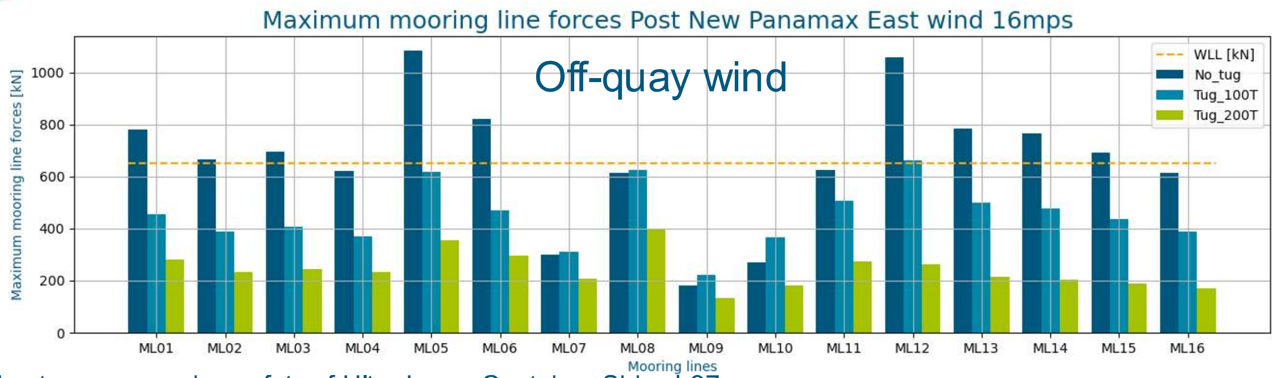
16 polyester lines
Minimum Breaking Load (MBL): 1300kN
Working Load Limit (WLL): 50% of MBL = 650kN

M.V EXPRESS ROME coming to SSIT port (source : HaivanSHIP)

2 Effect of tug assistance

- Significant reduction maximum line forces
- Tugs push ship into fenders, resulting in less dynamic response

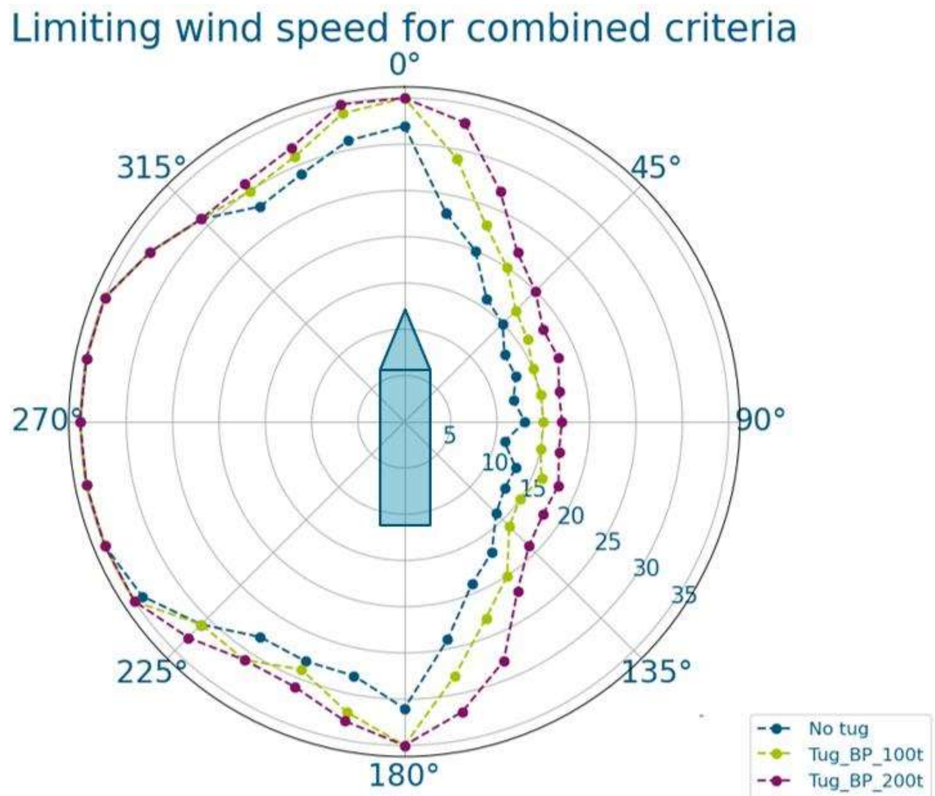




No tug assistance
100t tug assistance
200t tug assistance

2 Effect of tug assistance

- Limiting wind speed: maximum mooring line force ≤ Working Load Limit
- Circa 2-4 m/s increase of limiting wind speed (based on 100-200t tug force)
- Tug assistance is effective but involved costs can also be high
- More importantly, tugs are not always available



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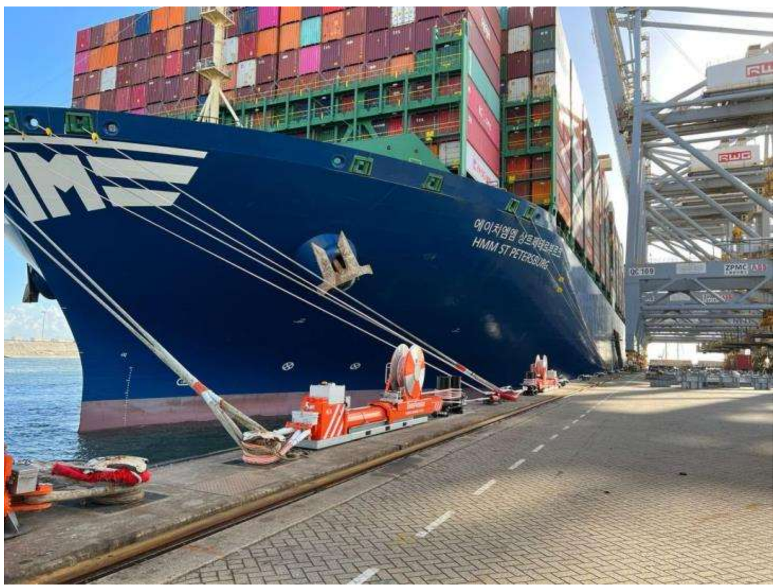
3 ShoreTension® mooring system

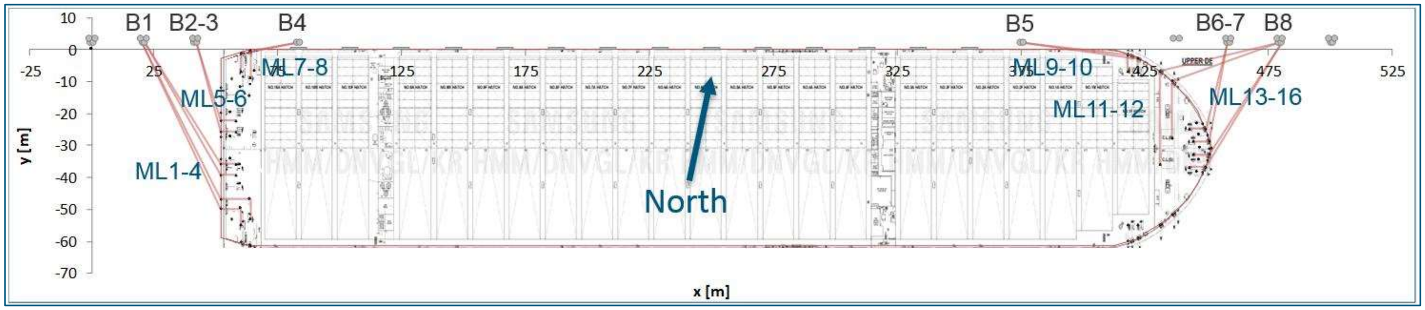
- Flexible stand-alone mooring system, based on a permanent tension of shore mooring lines (www.shoretension.com)

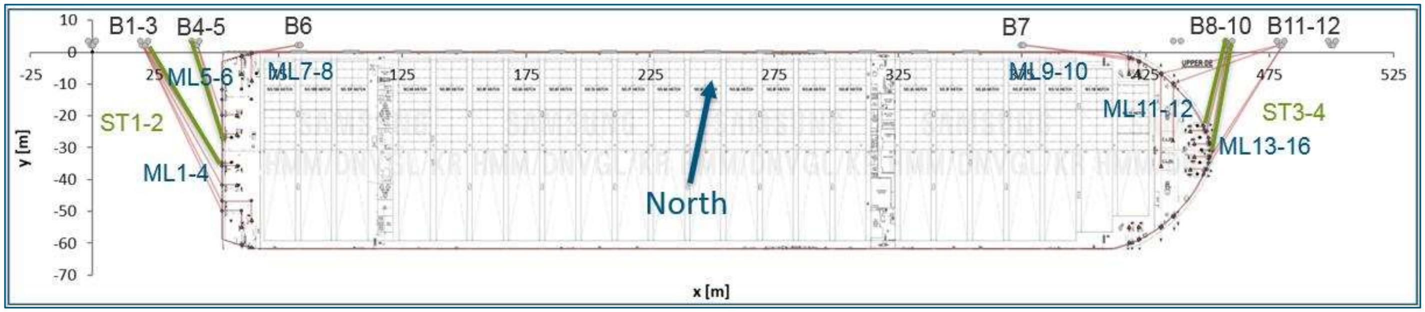


source: https://shoretension.com/news/shoretension-for-rotterdam-maasvlakte-ii/

3 ShoreTension® mooring system

- Example for HMM Oslo: 400m / 24,000 TEU
  - Four ShoreTension units



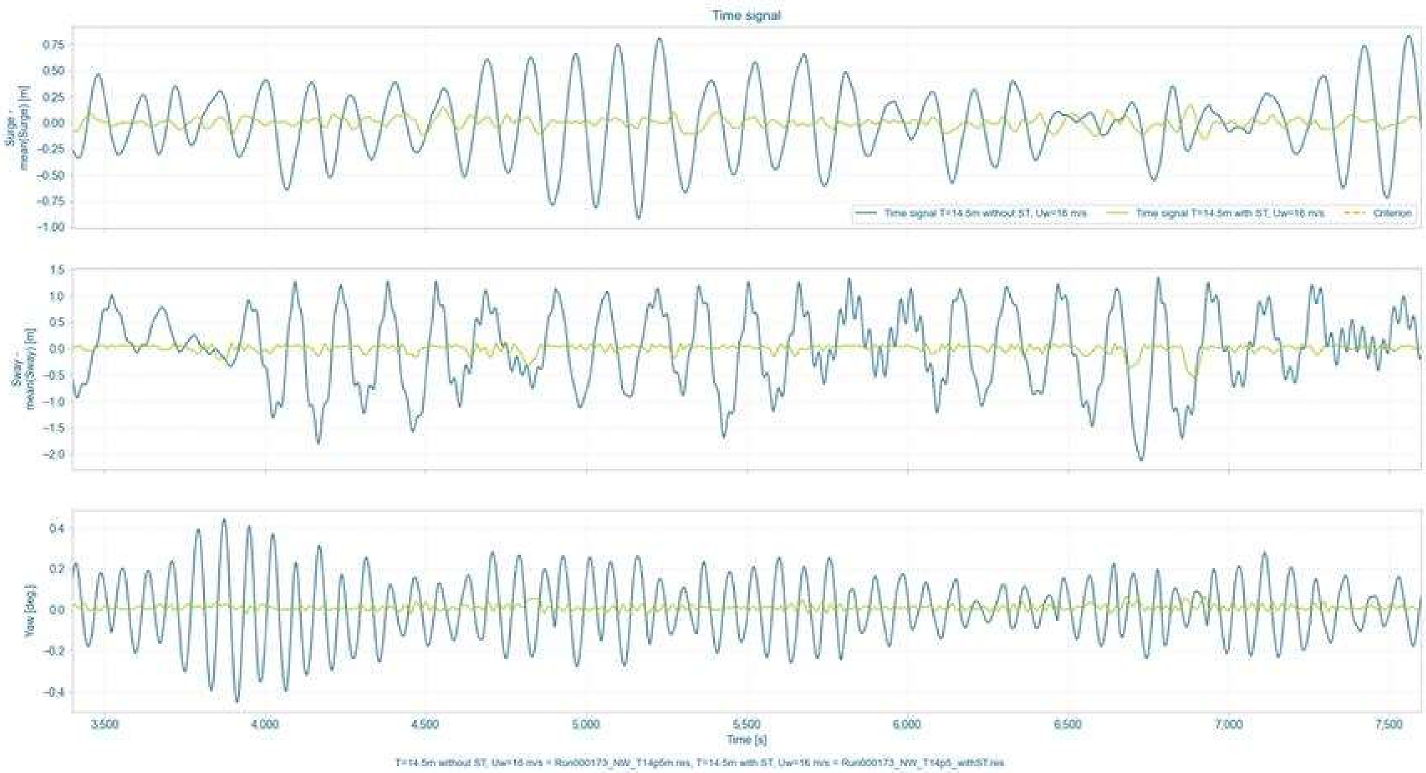


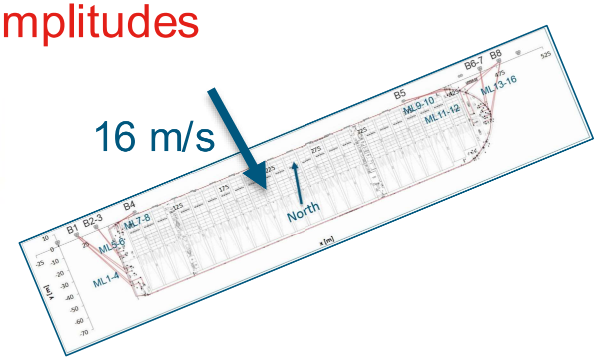
Mooring arrangements HMM Oslo (bottom mooring arrangement including ShoreTension®)

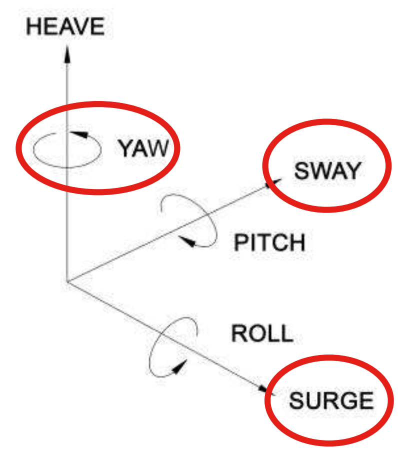
3 ShoreTension® mooring system

- Surge, sway and yaw motion for T=14.5 m
- With and without four ShoreTension® units

Significant reduction motion amplitudes

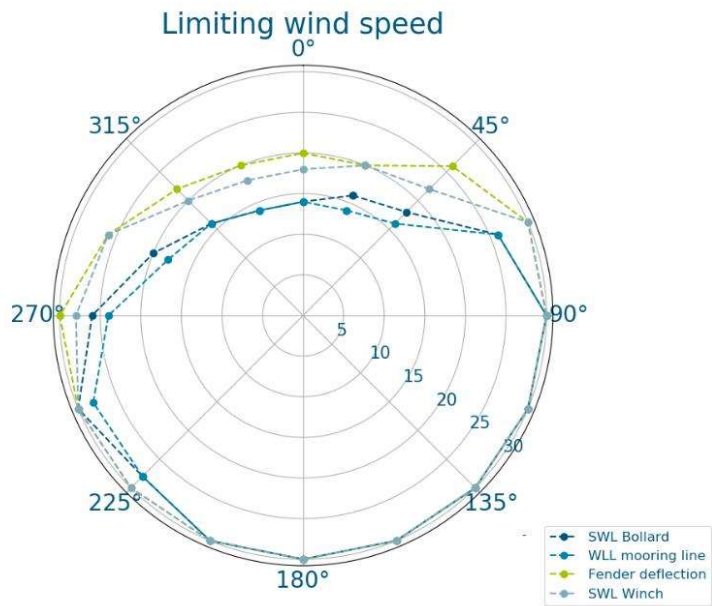


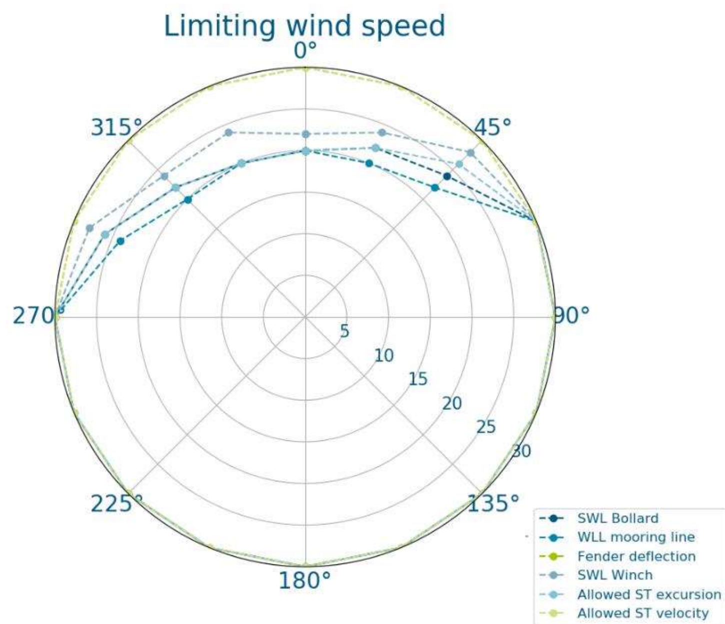




3 ShoreTension® mooring system

- Circa 5 m/s increase of limiting wind speed (four Shoretension units)
- Required: sufficient space on quay, sufficient number and capacity of bollards

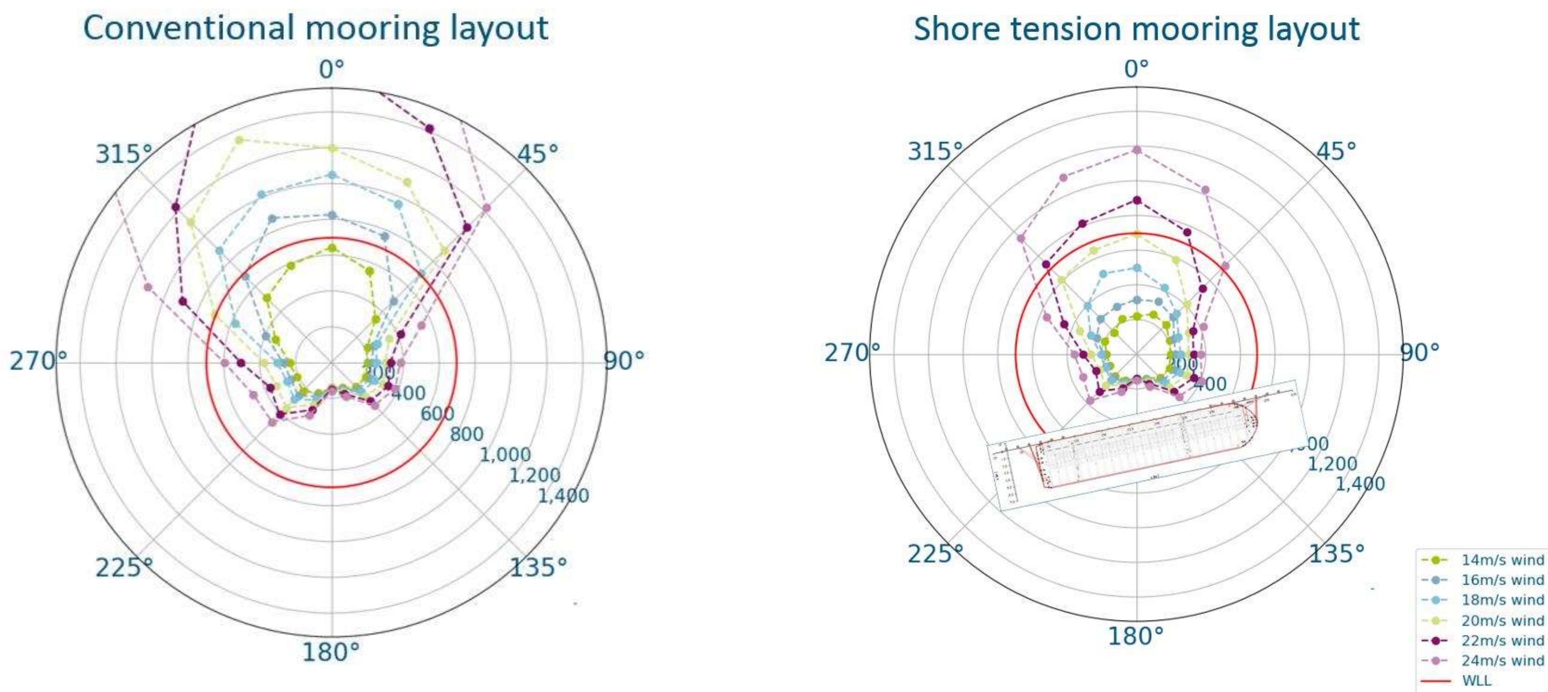




Polar plots limiting wind speeds HMM Oslo: excluding (left) and including ShoreTension® (right)

3 ShoreTension® mooring system

- Example for HMM Oslo: 400m / 24,000 TEU



Polar plots maximum line forces HMM Oslo: excluding (left) and including ShoreTension® (right)

Conclusion

- We use Dynamic Mooring Analysis to understand the moored ship behaviour in ports,
- with the purpose to improve the mooring to enable higher throughputs in ports and to ensure safer mooring.

- Several possibilities to improve the mooring of large container ships in wind are:
  - Crossed mooring arrangement
  - Tug assistance
  - ShoreTension®
  - Dynamoor (Trelleborg)

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Conclusion

- We use Dynamic Mooring Analysis to understand the moored ship behaviour in ports,
- with the purpose to improve the mooring to enable higher throughputs in ports and to ensure safer mooring.

- **The most cost-effective solution depends on**
  - **the number of tugs available,**
  - **on the number of visits of large container ships,**
  - **on the wind conditions in the port and**
  - **on the existing quay infrastructure.**

- Another solution to avoid unsafe situations is response predictions based on wind forecasts:
  - Smart Mooring | Royal HaskoningDHV