PIANC French Section

# PIANC Mediterranean Days

## and Conference «Port of the future» by Cerema

## 25 to 27 october 2023 in Sete France

# THE BEHAVIOUR OF A MOORED SHIP IN WIND: THE DIFFERENCE BETWEEN A STATIC AND DYNAMIC MOORING ANALYSIS

Lutz Schweter – Aktis Hydraulics

Speaker: Luis López – Aktis Hydraulics

# Aim of the paper

Joint effort from four consulting engineering professionals
From different companies specialized in Mooring Analysis

Differences between Static / Dynamic mooring analysis (SMA/DMA)
Dynamic amplification Factor (DAF)

Dynamic response moored ship
Results real projects (ship moored in wind only)


| | | |
|---|---|---|
| SCHWETER Lutz | lutz.schweter@aktishydraulics.com | Aktis Hydraulics |
| MISIAG Wojciech | wojciech.misiag@arcadis.com | Arcadis |
| LOPEZ Luis | lopez@aktishydraulics.com | Aktis Hydraulics (Siport XXI) |
| VAN DEYZEN Alex | alex.van.deyzen@RHDHV.com | Royal HaskoningDHV |

# Aim of the paper

**The paper contains two examples:**

- **SuezMax Tanker moored at a jetty**
- **A Post New-Panamax container ship moored at a quay**

**This presentation shows the example for the SuezMax Tanker**




**Mooring analysis of a ship moored to a quay in wind**

**To determine mooring safety (mooring equipment)**
**Mooring lines / Bollards / Fenders**

**i.e. limiting wind speeds / downtime**

Aktis Hydraulics

# Difference between Static & Dynamic Mooring Analysis

- Show that a SMA for large ships in wind yields optimistic results
- Show results mooring analysis for one case
  SuezMax to be moored AfraMax Terminal
- DMA: Hourly mean wind speeds
- SMA: 10-minute mean and 30-seconds gust wind speeds
- Dynamic Amplification Factor (DAF):
  Ratio maximum mooring line force based on DMA / SMA

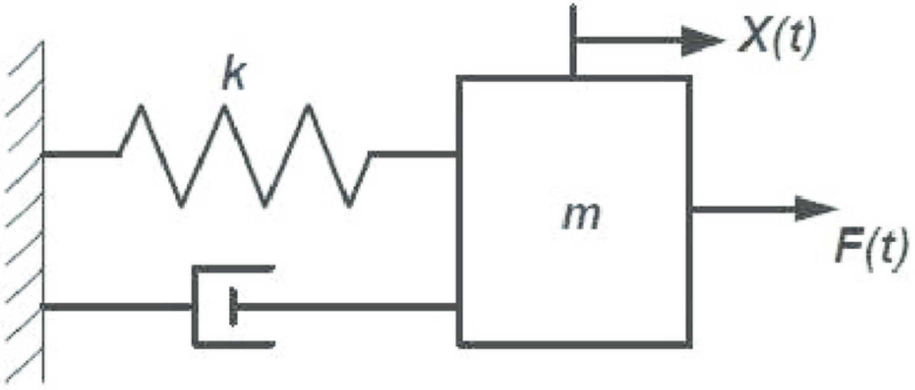

Aktis Hydraulics

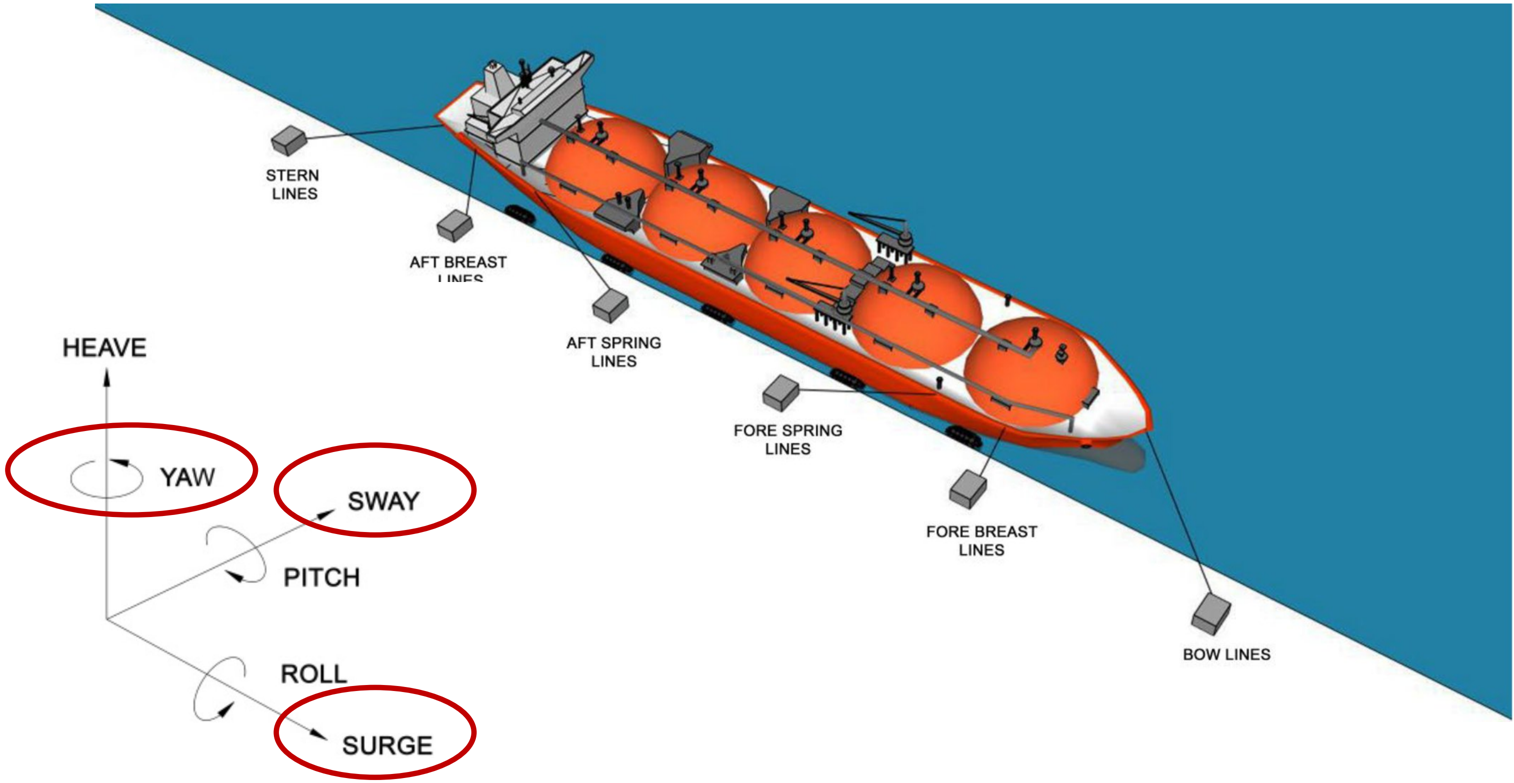
# Theoretical background

- Moored ship in wind = forced mass-spring system in 6 degrees of freedom

- Excited in 6 degrees of freedom  -  Focus motions horizontal plane

- Force = wind   (waves, current, passing ships, …)
- Ship = mass
- Spring = lines & fenders (non-linear)



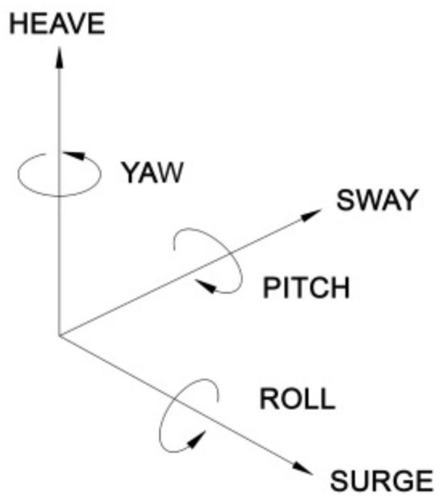

Aktis
Hydraulics

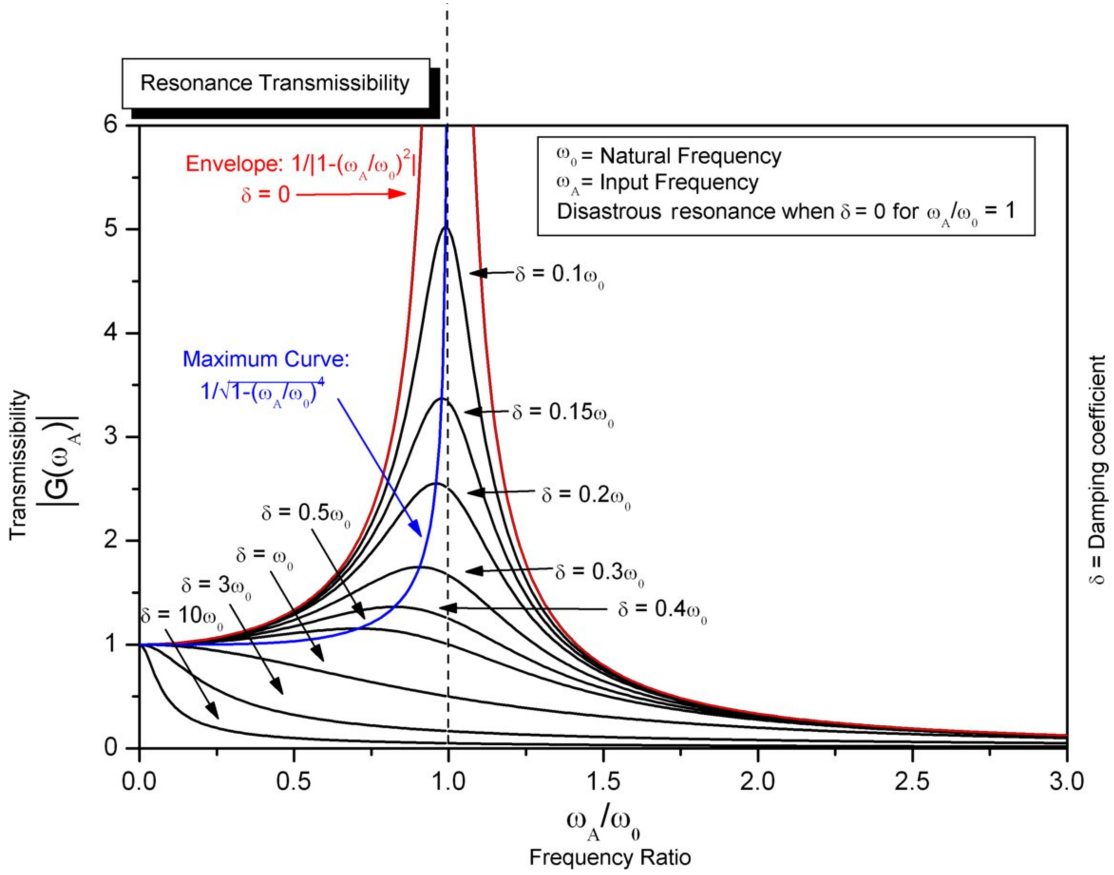
# Theoretical background

- **Theoretical approach showed for a simplified 1 DoF**

- **DAF depends on the dynamic characteristics of the system**
  - ratios for mass, spring characteristics and damping
  - governing the natural frequencies of the system

- **For the response of a moored ship:**
  - Additional coupling effects between the 6 DoF




Aktis Hydraulics

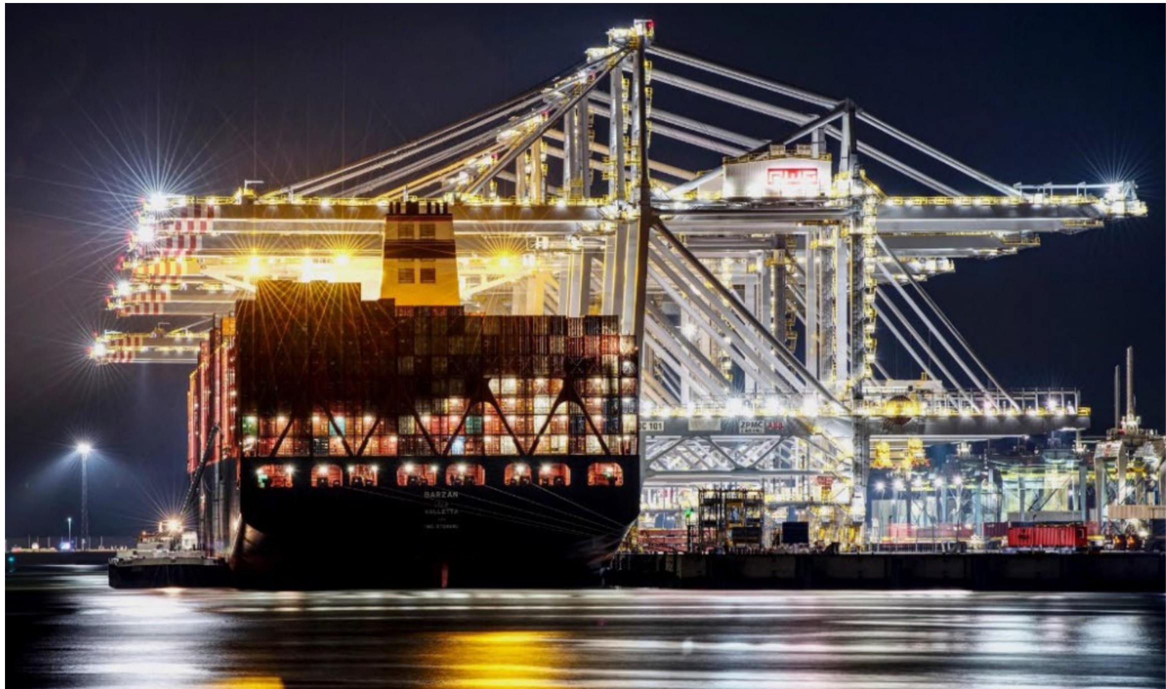
# Methodology

- The difference between Static & Dynamic Mooring Analysis

- Show results mooring analysis for the moored SuezMax Tanker

- Applied software for both SMA & DMA:
- Ship-Moorings: To solve equations of motion in time domain
  Arcadis (Alkyon)
- Diffrac: To include added mass and damping ship in water
  Marin (www.marin.nl)

$$((M + a_{nn})\ddot{\bar{X}}) + (b_{nn}\dot{\bar{X}}) + (c_{nn}\bar{X}) = \bar{F}_{wind}(t)$$



Aktis Hydraulics

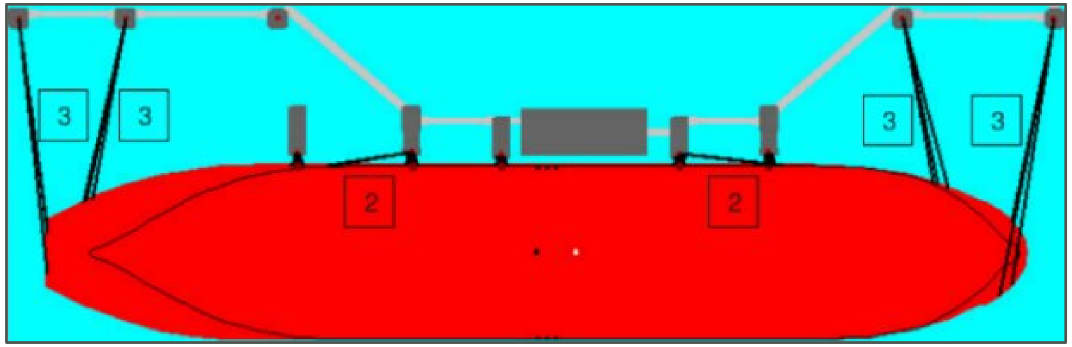
# Methodology

- Main particulars

- Ballast condition (high windage area)

- 8 double drum winches
- 16 mooring wires (Minimum Breaking Load MBL 83.3t)
- with nylon tails (MBL 110t, WLL 55t)
- Working Load Limit (WLL 45.8t) - 55% MBL (OCIMF)

| Design ship | Suezmax tanker |
|---|---|
| Cargo capacity DWT | 158,000 t |
| Length over all LOA | 274.0 m |
| Beam B | 48.0 m |
| Draught T | 7.6 m |
| Displacement Δ | 78,500 t |
| Transverse windage area Awt | 1,330 $m^2$ |
| Longitudinal wind area Awl | 5,530 $m^2$ |




Aktis Hydraulics

# Methodology

- **Wind conditions:**
  - Average wind speed – 1-hour averaged wind speed $U_{3600}$
- **Static Analysis**
  - 30-s averaged wind speed $U_{30}$
- **Dynamic Analysis**
  - API spectrum
  - 30-s gust wind speed
  - API (gust factor of 1.265)
  - The variation in the wind direction Udir
  - Simiu & Scanlan (1986)
  - 10 realizations

| Udir [°N] | $U_{3600}$ [kn] | $U_{30}$ [kn] |
|---|---|---|
| 0-330 in 30° steps | 25, 30, 35, 40, 45, 50, 55 | 32, 38, 44, 51, 57, 63, 70 |

Aktis Hydraulics

# Results

- ## Maximum Line Loads

**Off-Shore winds** **Shore winds**

| Maximum line loads [kN] | Udir [°N] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| u | 0 | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 |
| DYNAMIC u3600=50kn | 412 | 150 | 104 | 125 | 173 | 239 | 381 | 845 | 948 | 1022 | 857 | 532 |
| STATIC [u=u3600] u=50kn | 240 | 137 | 90 | 79 | 123 | 174 | 183 | 222 | 268 | 228 | 223 | 167 |
| $DAF_{3600}$ | 1.7 | 1.1 | 1.2 | 1.6 | 1.4 | 1.4 | 2.1 | 3.8 | 3.5 | 4.5 | 3.8 | 3.2 |
| STATIC [u=u30] u=63kn | 389 | 189 | 96 | 81 | 159 | 271 | 284 | 369 | 436 | 372 | 367 | 242 |
| $DAF_{30}$ | 1.1 | 0.8 | 1.1 | 1.6 | 1.1 | 0.9 | 1.3 | 2.3 | 2.2 | 2.7 | 2.3 | 2.2 |
| STATIC [u=u30] incl. safety factor 1.5 | 584 | 283 | 145 | 121 | 239 | 407 | 426 | 554 | 653 | 557 | 551 | 363 |
| $DAF_{30}$ | 0.7 | 0.5 | 0.7 | 1.0 | 0.7 | 0.6 | 0.9 | 1.5 | 1.5 | 1.8 | 1.6 | 1.5 |
| DYNAMIC u3600=35kn | 159 | 111 | 90 | 103 | 118 | 143 | 157 | 349 | 454 | 406 | 345 | 185 |
| STATIC [u=u3600] u=35kn | 139 | 106 | 85 | 77 | 98 | 118 | 122 | 116 | 128 | 111 | 104 | 118 |
| $DAF_{3600}$ | 1.1 | 1.1 | 1.1 | 1.3 | 1.2 | 1.2 | 1.3 | 3.0 | 3.5 | 3.7 | 3.3 | 1.6 |
| STATIC [u=u30] u=44kn | 189 | 123 | 88 | 78 | 112 | 149 | 156 | 175 | 205 | 178 | 173 | 146 |
| $DAF_{30}$ | 0.8 | 0.9 | 1.0 | 1.3 | 1.1 | 1.0 | 1.0 | 2.0 | 2.2 | 2.3 | 2.0 | 1.3 |
| STATIC [u=u30] incl. safety factor 1.5 | 283 | 184 | 132 | 117 | 168 | 224 | 233 | 263 | 308 | 267 | 259 | 219 |
| $DAF_{30}$ | 0.6 | 0.6 | 0.7 | 0.9 | 0.7 | 0.6 | 0.7 | 1.3 | 1.5 | 1.5 | 1.3 | 0.8 |

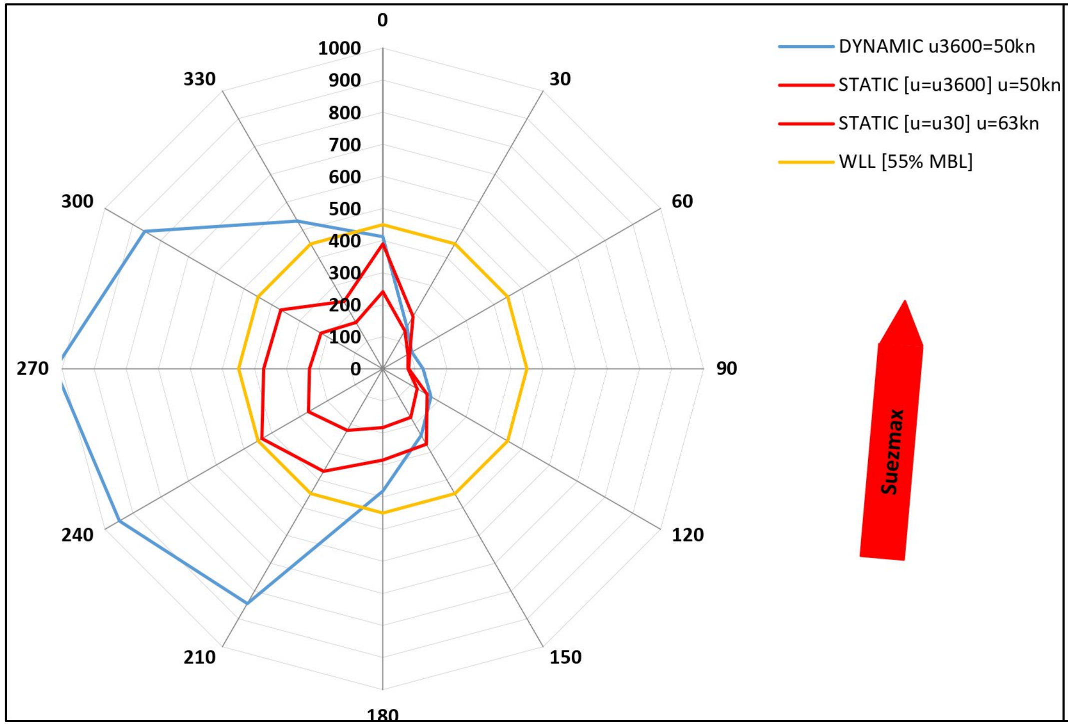
**SMA based on $U_{30}$**

| | | | |
|---|---|---|---|
| **270º** | **DMA = 1022 kN** | **SMA = 372 kN** | **DAF = 2.7** |
| **90º** | **DMA = 125 kN** | **SMA = 81 kN** | **DAF = 1.6** |

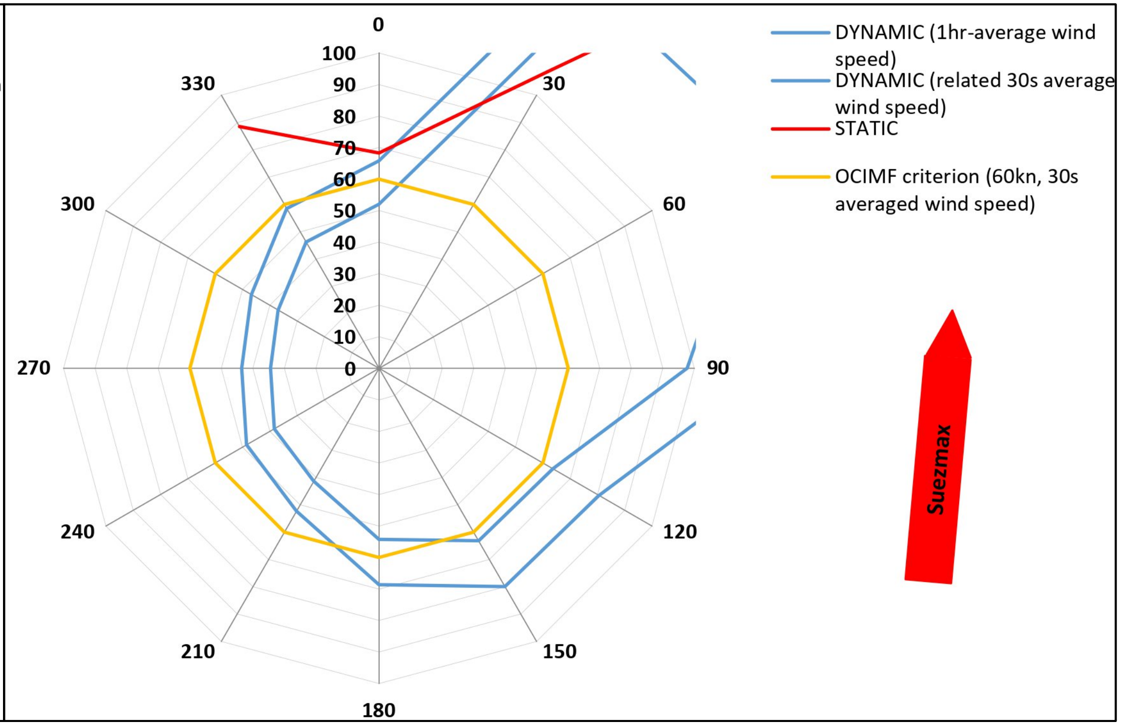
Aktis Hydraulics

# Results

## Maximum Line Loads




## Limiting wind speed

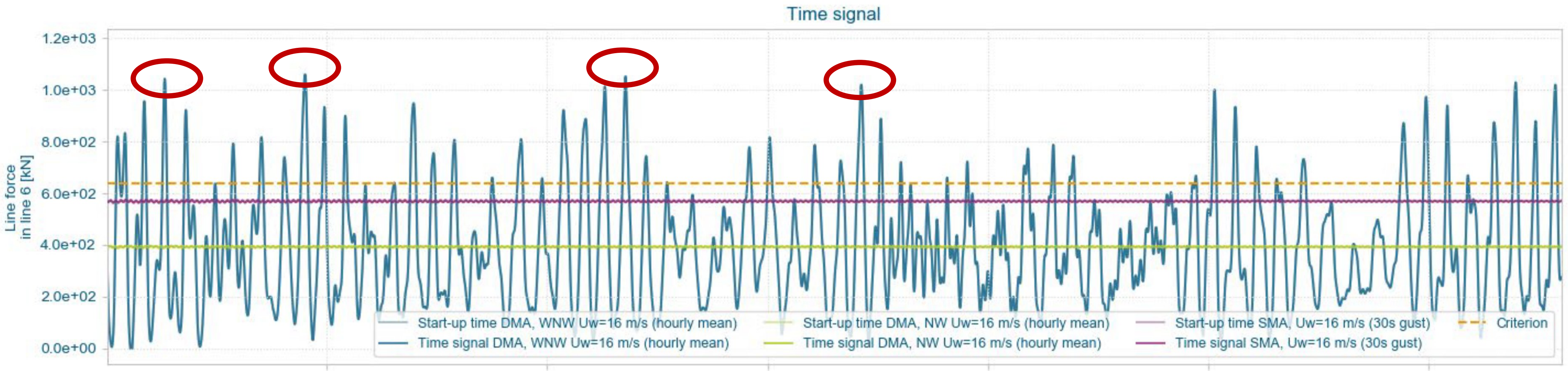



Aktis Hydraulics

# Results

## Maximum Line Loads time series – Containership project

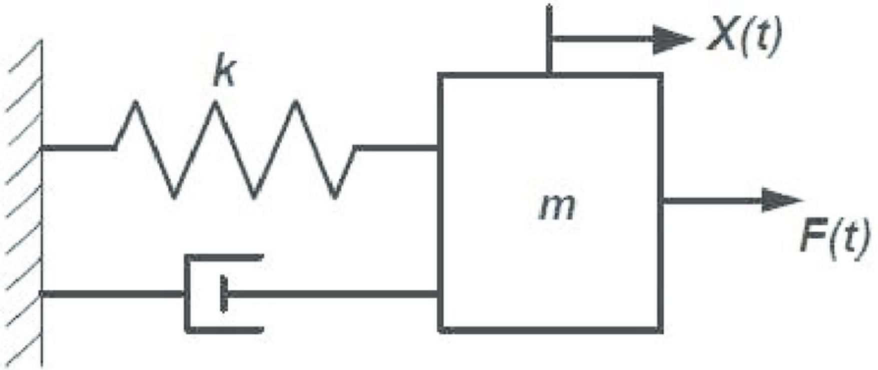
## Peak loads – Dynamic response of the ship




Aktis Hydraulics

# Conclusions

- **There is a significant difference between the maximum line (and bollard) force determined by a SMA and DMA**
  - SMA safe conditions / DMA non-safe conditions
  - Other Containerships, RoRo, Cruise ships, …
- **A SMA for large moored container ships in wind yields optimistic results:**
  - Moored ship responds dynamically to gusting wind
  - Resulting in large peak loads in the lines
  - Large peak loads not modelled in a SMA
- **Dynamic response depends on various parameters, basically:**
  - Wind force (varying in time), mass and spring, e.g.:
    - Displacement, mooring configuration, line specifications, etc.




Aktis Hydraulics

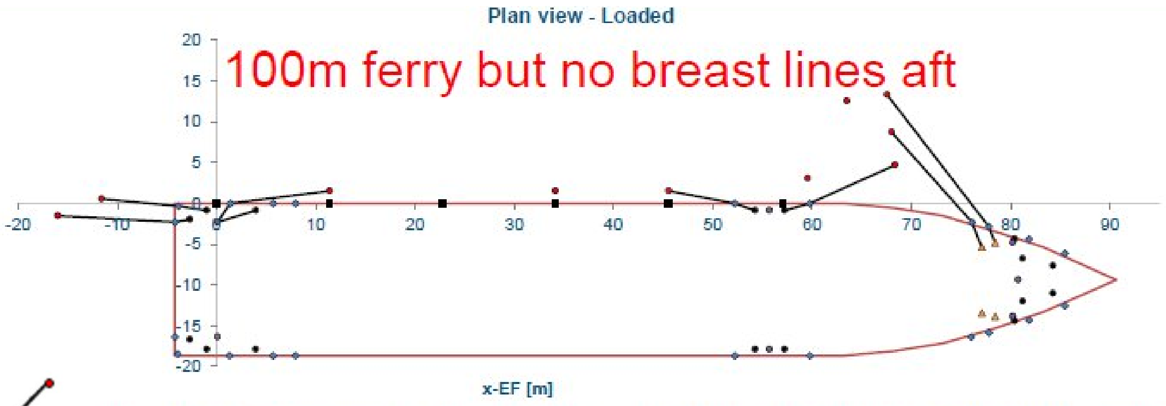
# Conclusions

- **Shore winds / Offshore winds (Fenders!)**
- **Applying 30s gust wind in combination with a DAF helps but it is not an accurate description of the physics**
- **For considered mooring case is the DAF is equal to 0.8 to 2.7  (2.0 to 2.5 other case):**
  - DAF: Ratio maximum mooring line force based on DMA / SMA (wind angle / speed)
  - **Safety factor = 3.0!** (ROM 0.2-90  dynamic factor 2.0)
- **Important when doing a SMA:**
  - In general, what value for the DAF will you apply? How do you know?
  - And last but not least, what do you win by doing a SMA including DAF compared to a DMA?

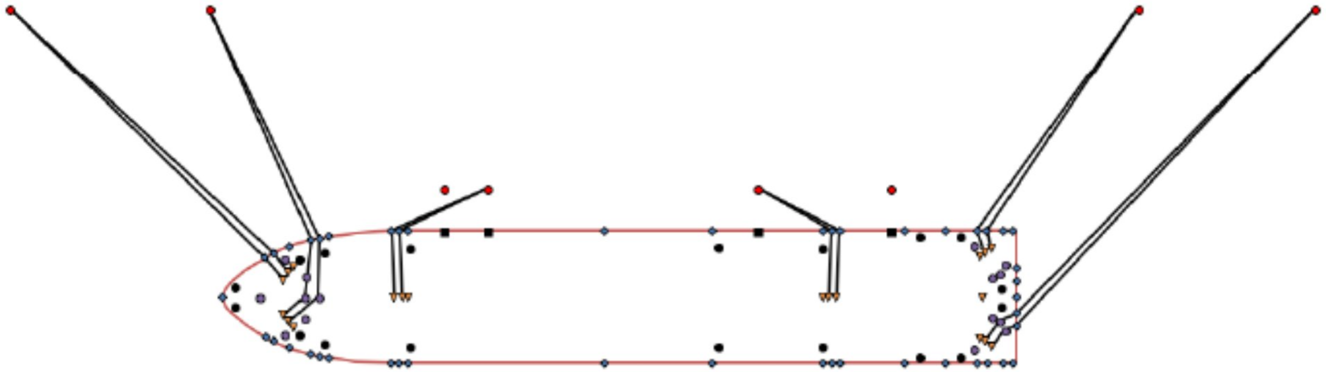
Aktis Hydraulics

# Conclusions

- **Large difference between SMA and DMA for a ship in wind also visible for:**
  - Long lines
  - (Far) from ideal mooring arrangement
  - Basically, in case of a soft spring




27k m$_3$LNG carrier (180m) to a jetty that was designed for larger LNG carriers



- **Further developments:** **Apply DAF to any kind of time-varying loads**
  - Waves, current, passing ship effect, …

Aktis Hydraulics