PIANC Workshop
13-14th September 2011

Part 5: Mooring forces and vessel behaviour in locks – Experience in Belgium

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BELGIUM

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Mooring forces and vessel behaviour in locks: Experience in Belgium

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flanders HYDRAULICS RESEARCH
Antwerp

MARITIEME TECHNIEK UNIVERSITEIT GENT
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Mooring forces

Classical approach to ensure smooth and safe F/E of lock: "**hawser force** criterion"

- misleading term
- **hydrodynamic force** exerted by water on should be below a given **threshold value**
- measure force on (centrally positioned) vessel in **scale model** (no mooring lines)

Mooring forces

Threshold values for **inland** navigation:

- popular value for quite sometime:
  1‰ of displacement weight
- since 1980's (~neighbouring countries, mainly NL):

CEMT class	LxBxT	Filling (fixed bollards)	Filling (floating bollards), emptying
IV	80m x 9.45m x 2.8m	1.1 ‰	1.5 ‰
Va	135m x 11.4m x 3.5m	0.85 ‰	1.15 ‰
Vb	190m x 11.4m x 3.5m	0.75 ‰	0.75 ‰

Conservative…? (in comparison to on site measurements)

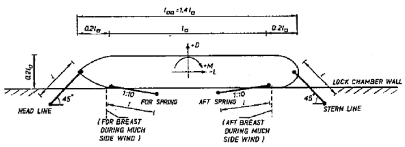
Recreational vessels: 3 ‰

- relative approach: e.g. actual situation normative for situation after renovation of F/E system

Mooring forces

Threshold values for **sea-going** navigation:

- A. Vrijburcht (1977)



Conservative…?
(in comparison to on site measurements)

ship's size tons DW	rope's type	rope T_{pr}/T_u	criteria in $^o/_{oo}$ long. force x	transv. force y	moment z_1	z_2	z_3
40,000	steel	0.15	0.24	0.14	0.075	0.050	0.025
40,000	steel	0.10	0.15	0.10	0.051	0.034	0.017
40,000	nylon	0.20	0.26	0.20	0.102	0.068	0.034
40,000	nylon	0.10	0.14	0.10	0.051	0.034	0.017
80,000	steel	0.15	0.21	0.12	0.066	0.044	0.022
80,000	steel	0.10	0.13	0.085	0.044	0.029	0.015
80,000	nylon	0.20	0.22	0.16	0.087	0.058	0.029
80,000	nylon	0.10	0.115	0.08	0.043	0.029	0.015
120,000	steel	0.15	0.19	0.11	0.060	0.040	0.020
120,000	steel	0.10	0.12	0.08	0.041	0.027	0.014
120,000	nylon	0.20	0.205	0.16	0.081	0.054	0.027
120,000	nylon	0.10	0.105	0.08	0.040	0.027	0.013

- relative approach: e.g. existing lock normative for (± comparable) new lock

Mooring forces

Threshold values:

- (too?) often only longitudinal force component considered

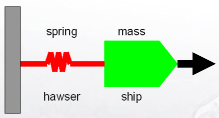
- $$\text{threshold} = \sum_{\text{mooring lines}} \frac{T_u \cos(\theta_i)\cos(\phi_i)}{f_s \cdot f_m}$$

T_u = minimum tensile strength

f_s = safety factor w.r.t. T_u

f_m = dynamic magnification factor

θ_i, ϕ_i = line orientation

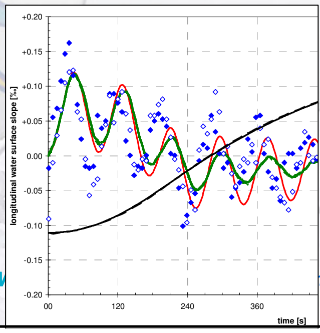


cf. H.-W. Partenscky (1986) ; A. Vrijburcht (1994) ; T. De Mulder (2007)

Mooring forces

Mathematical models for "**lateral**" F/E systems

- lock chamber flow based on Shallow Water Eqs. (1D or 2D)
- (pre)calculated timeseries of filling/emptying discharges
- vessel represented by means of artificial field of atm.pressure
- longitudinal water surface slope (bow-stern)

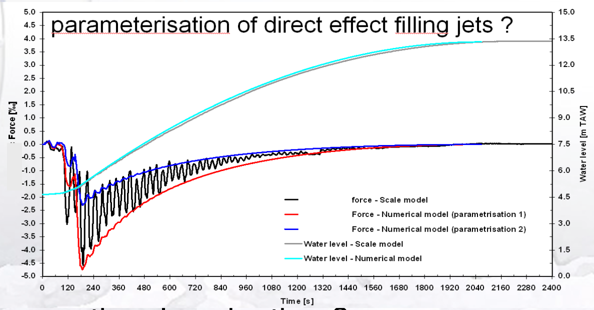


numerical predictions (LOCKSIM,DELFT3D)
and values measured on site

Mooring forces

Mathematical model for "**longitudinal**" F/E systems

- LOCKFILL (NL ; developed since 1990's)
- similar programme developed in house at FHR
- intensive validation



- recreational navigation ?

"Hawser Forces"

Numerical calculation / Physical model test on immobilized vessel

➔ (horizontal) force and moment components on ship due to Filling/Emptying = **"exciting forces"**

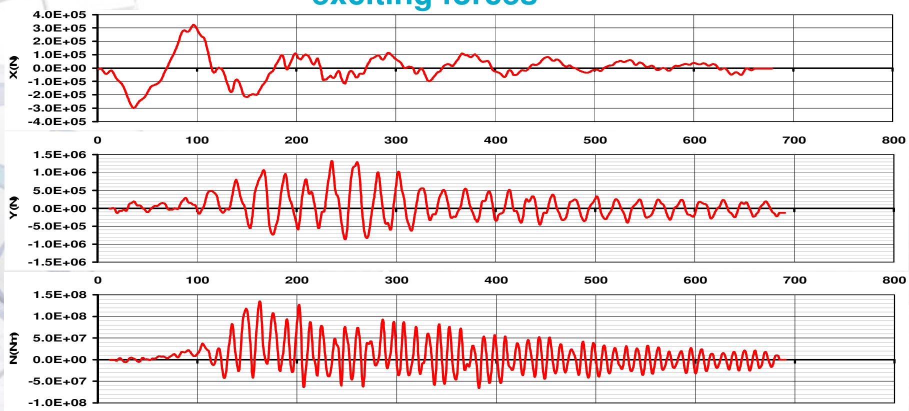
➔ to be applied to ship + moorings/control

➔ dynamic system

➔ forces in mooring system + lateral displacement

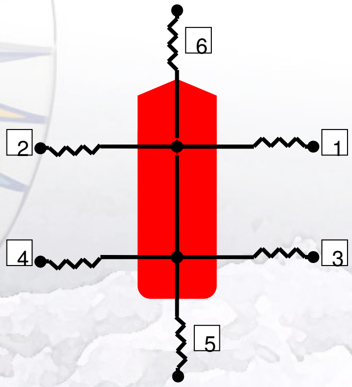
"Hawser Forces"

"exciting forces"



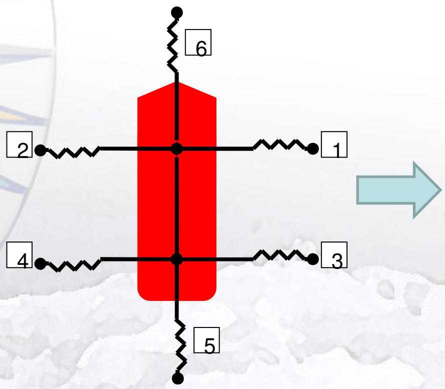
“Hawser Forces”

Dynamic system ?

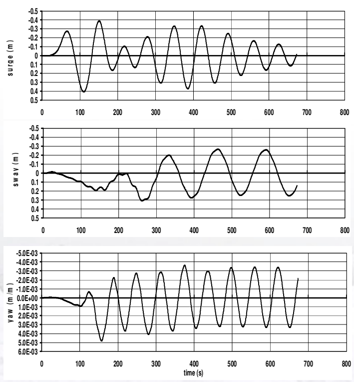


“Hawser Forces”

Dynamic system: pure springs

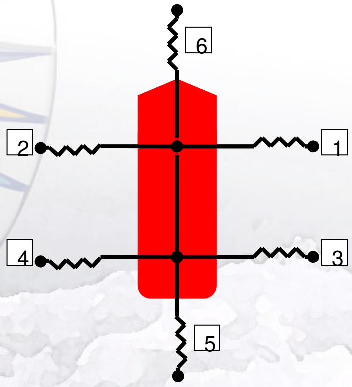


motions

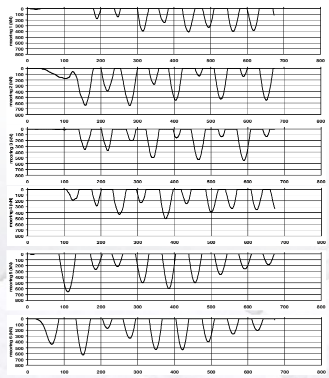


"Hawser Forces"

Dynamic system: pure springs



line forces



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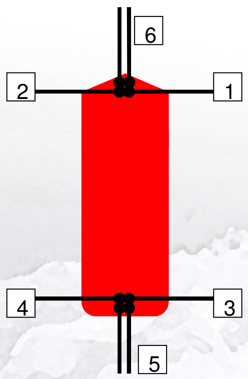
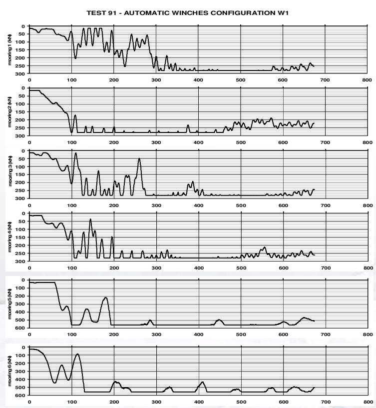
"Hawser Forces"

Dynamic system: automatic winches



line forces



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“Hawser Forces”

Increase realism:

- Realistic mooring configuration
- Vertical motion!
- Winch control

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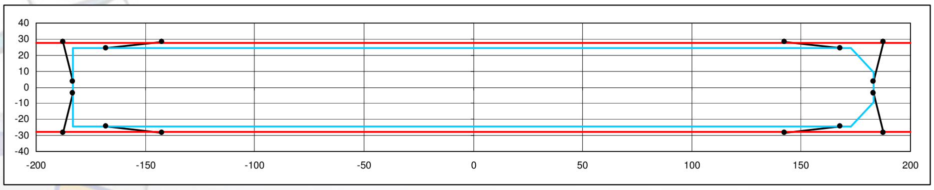
“Hawser Forces”



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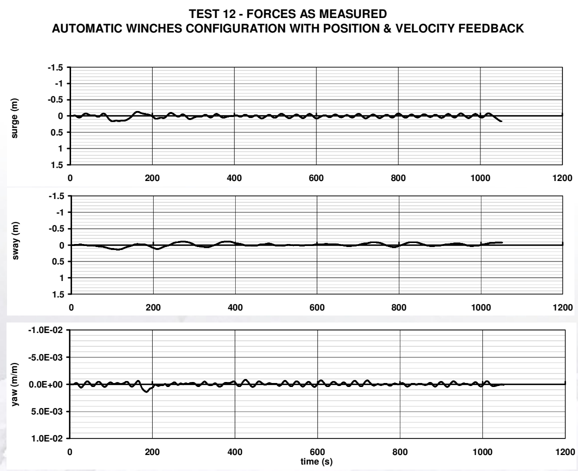
Setting the course

"Hawser Forces"

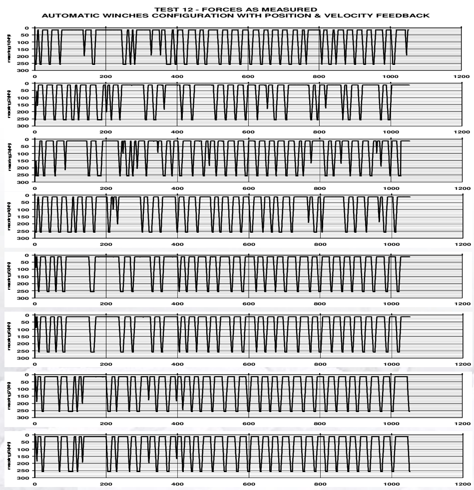
Control algorithm:

- Initially constant force of 0.2 MBS to each line.
- If bow/stern is closer to SB side of the lock, or if bow/stern is moving to SB, breast line fore/aft starboard will be rendered.
- If bow/stern is closer to PS of lock, or if bow/stern is moving to port, breast line fore/aft port will be rendered.
- If ship is moving ahead/astern, or if ship's position is ahead/astern of her initial position, springs fore/aft will be rendered.
- In case a line is rendered, it is assumed that line force is reduced to 1% of MBS. It is assumed that line length can be adjusted with a maximum speed of 0.25 m/s.
- During the simulations, the necessity of rendering the lines is evaluated with a time interval of 2 s.

"Hawser Forces"

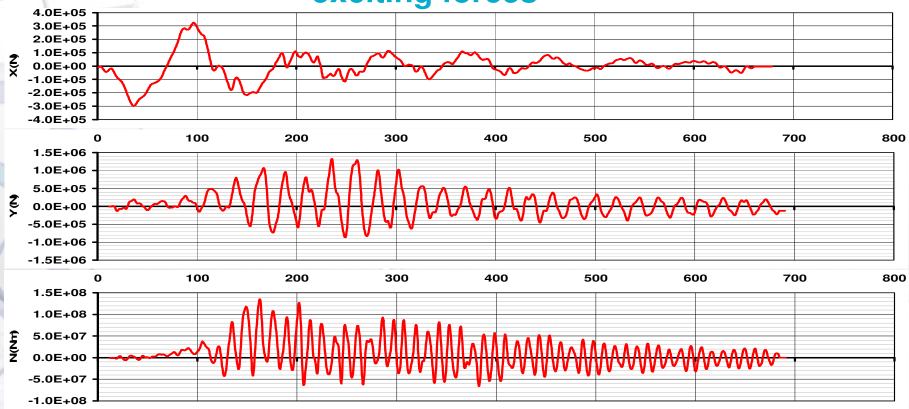


"Hawser Forces"



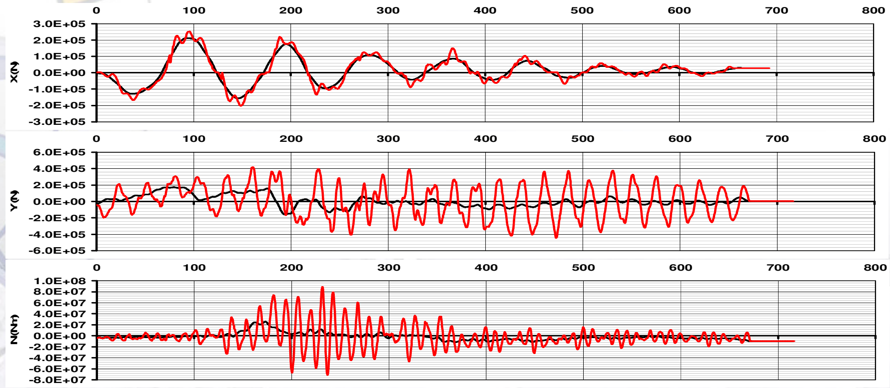
"Hawser Forces"

"exciting forces"



"Hawser Forces"

"exciting forces" ➔ running average



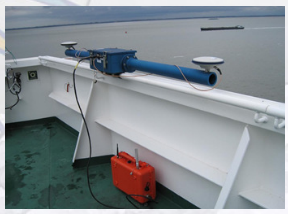
Mooring forces

On site measurements by FHR

Water surface slopes (end-to-end)

- with/without vessel(s) in lock
- ≈ hydrostatic force on vessel

Vessel motion



For on site measurements by

Wallonie SPW Service public de Wallonie

see D. Bousmar (Smart Rivers 2011)

More on mooring forces

• **T. De Mulder (2007):** *Specification of hawser force criteria.* Report TO1-Task 1.2.4-CNR-FHR-R013 of Consorcio Pos-Panamax, commissioned by ACP.

➔ Report n° 106 of PIANC WG 29 ; CD-ROM ; Directory C14

•**T. De Mulder (2009):** *Mooring forces and ship behaviour in navigation locks*. Paper 7 in Int. Workshop on "Innovations in Navigation Lock Design", PIANC-Brussels, 15-17 Oct. 2009.

➔ http://www-new.anast.ulg.ac.be/index.php/fr/nouveautes/40/94-pianc-workshop-innovations-in-navigation-lock-designg

• **T. De Mulder et al. (2010):** *On hawser force criteria for navigation lock design: Case study of maritime locks in Port of Antwerp.* Paper 290 in Proc. PIANC MMX Congress, Liverpool-UK, 10-14 May 2010.

More on mooring forces

• **on site tests & inquiries** at stakeholders

(e.g. systematic variation of valve opening laws)

• **intercomparison** of scale models, numerical models, on site measurements

- in **absolute** terms (?)
- in **relative** terms (!): for a given lock (+vessel), do results show the same **trends?**

  w.r.t. influence on peak force / peak slope of:

  ➔ initial head

  ➔ valve opening time

  ➔ distance bow to filling gate

  ➔ ship size (displacement, blockage,…)

  ➔ etc.