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

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Mooring forces and vessel behaviour in locks: Experience in Belgium

T. De Mulder & M. Vantorre

www.pianc.org New-Orleans 2011
Mooring forces

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

- misleading term

- **hydrodynamic force** exerted by water on vessel should be below a given threshold value

- measure force on (centrally positioned) vessel in **scale model** (no mooring lines)

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Mooring forces

Threshold values for **inland** navigation:

- popular value for quite sometime:
  1% of displacement weight

- since 1980’s (~neighbouring countries, mainly NL):

<table>
<thead>
<tr>
<th>CEMT class</th>
<th>LxBxT</th>
<th>Filling (fixed bollards)</th>
<th>Filling (floating bollards), emptying</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>80m x 9.45m x 2.8m</td>
<td>1.1 %</td>
<td>1.5 %</td>
</tr>
<tr>
<td>Va</td>
<td>130m x 11.4m x 3.5m</td>
<td>0.85 %</td>
<td>1.15 %</td>
</tr>
<tr>
<td>Vb</td>
<td>180m x 11.4m x 3.5m</td>
<td>0.75 %</td>
<td>0.75 %</td>
</tr>
</tbody>
</table>

  - Conservative...? (in comparison to on site measurements)

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

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Mooring forces

Threshold values for sea-going navigation:

- A. Vrijburcht (1977)

Threshold values:

- (too?) often only longitudinal force component considered

\[
\text{threshold} = \sum_{\text{mooring lines}} \frac{T_e \cos(\theta_e) \cos(\phi)}{f_s f_m}
\]

- \(T_e\): minimum tensile strength
- \(f_s\): safety factor w.r.t. \(T_e\)
- \(f_m\): dynamic magnification factor
- \(\theta_e, \phi\): line orientation

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

parameterisation of direct effect filling jets?
“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

“exciting forces”

<table>
<thead>
<tr>
<th>X (N)</th>
<th>Y (N)</th>
<th>N (N m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.5E+06</td>
<td>-1.0E+06</td>
<td>-5.0E+05</td>
</tr>
<tr>
<td>0.0E+00</td>
<td>5.0E+05</td>
<td>1.0E+06</td>
</tr>
<tr>
<td>1.5E+06</td>
<td>1.0E+06</td>
<td>5.0E+05</td>
</tr>
</tbody>
</table>

www.pianc.org  New-Orleans 2011  PIANC  Setting the course
“Hawser Forces”

Dynamic system?

Dynamic system: pure springs motions
“Hawser Forces”

Dynamic system: pure springs

Dynamic system: automatic winches

line forces
“Hawser Forces”

Increase realism:
- Realistic mooring configuration
- Vertical motion!
- Winch control
“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”

“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
see D. Bousmar (Smart Rivers 2011)
More on mooring forces

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


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.