Mooring forces and ship behavior in locks (and lock approaches)
German experiences
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Allowable ship force for inland navigation vessels during locking

A lock in canal near Chester / England
www.pianc.org New-Orleans 2011
Allowable ship force for inland navigation vessels during locking

For a 110 m ship (~3200 t), selfpropelled:

• BAW-inhouse criterion for allowable ship force: < 23 kN

• Based on studies by Partenscky and others taking into account hawser geometry, ship dynamics as a spring-mass system, security factors, hawser slack and pretension, some magic numbers ....
Allowable ship force for inland navigation vessels during locking

- German Lloyd's has (had?) requirements for hawsers depending non-linearly on ship mass
  (for 3200 t ship: Four hawsers of 206 kN)

- “It is generally accepted, that the hawser force should be less than 1/600 of ship mass force” (1951, for a 3200 t ship this means: 53 kN)

Hawser strength versus load

Security depends on ship mass?!
Hawser pretension

Reaction force of pretensioned hawsers
Typical ship force measurement

Decomposition: Filling effects
Decomposition: Sloshing

Ship forces versus hawser forces

- Ship moves back and forth during locking
- Hawser pretension is assumed to be “man pulled” with 0.3 kN
- Remaining line slack allows ship to “hammer” into the hawsers

⇒ Difference between 23 kN and ~200 kN is reserve for the dynamic behavior, mishandling of hawsers...
What about the results?

• Partenscky ended up after lot’s of computation with a max. slope of 0.4 \(0/00\)

• But the Dutch colleagues use 0.8 \(0/00\) ?

• Well, with the assumption of a little more pretension and slightly shorter hawsers we can use that, too …

• Then, a BAW colleague converted this with some magic into 23 kN

The times, they are a changing’

23 kN max. ship force is “fixed”, though hawser strength requirements changed:

1953: Hawser strength > 511 kN (!)
1976: Hawser strength > 206 kN per hawser (4x)
today: ???

and required design load for bollards changed in the DIN code:

100 kN ‘til the 70th
200 kN today
Evaluation methods for the 23 kN

- Physical model tests

Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex
- 3D-CFD model (or hydraulic model) for flow in inlet/outlet, chamber, ...
Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex
- 3D-CFD model (or hydraulic model) for flow in inlet/outlet, chamber, ...

- 2D-CFD model (or 3D-CFD or hydraulic model) for flow in approach areas, adjacent rivers or canals

Evaluation methods

Simplified geometrie modell for 3D-Simulation
Evaluation methods

3D-Simulation of filling process
Evaluation methods

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Evaluation methods

3D-Simulation of filling process

Comparison of numerical and physical model test results
Evaluation of ship forces

- Physical models and numerical models deliver reliable results

- Ship force is a far, far away from real hawser forces

- ... but they are a reliable, repeatable, measurable quantity, while hawser forces rely on uncertain parameters

Evaluation: Known accidents

- Some accidents because of wrong handling of hawsers

- Some accidents because of misoperation of the lock

- Some accidents during entering / leaving the lock

- No known accidents because of “high loads” on the hawsers because of the filling process
Guidelines for flow field in the approaches

- Based on force balances for a ship that tries to enter a canal

- Valid for entering a lock?

⇒ Old guideline: Max. 0.3 m/s transversal flow, to be reduced “under special circumstances”

Lock approaches: Simulator

Navigation simulator for critical situations. Human factor?
Lock approaches: Simulator

• Based on a simulator for seagoing vessels by Rheinmetall Defense Electronics (RDE)

• Recalibration for inland navigation vessels and changes for narrow, constraint fairways finished

• Integrated physical assumptions clearly not valid for entering the lock => Future work: Real-time CFD

Summary

• Reliable approaches to evaluate forces on a ship in the lock
• Many (unreliable) parameters (hawser pretension, angles, dynamics, human factors) impact forces in the hawsers
• Ship behavior in approaches depends on pilots skills. How to put that in numbers?
  => Hopefully WG155 will find some answers to these questions. Let’s have a look later ...