PIANC Workshop
13-14th September 2011

# 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



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# Allowable ship force for inland navigation vessels during locking

Sportbootverkehre an ausgewählte Strecken

Schleuse Canow



# 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 ….**

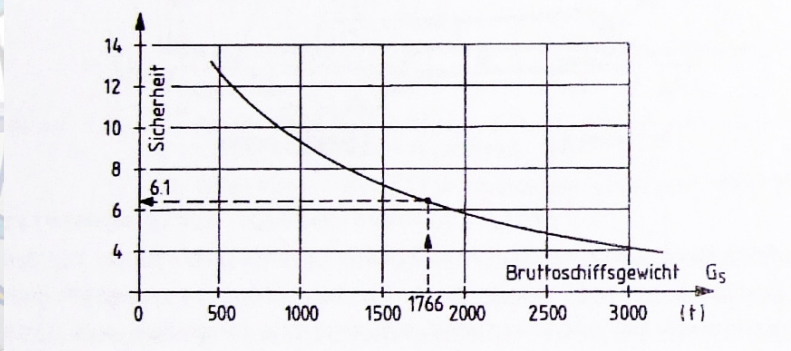
# Allowable ship force for inland navigation vessels during locking

- German Lloyd's has (had?) requirements for hawsers depending non-linearily 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)

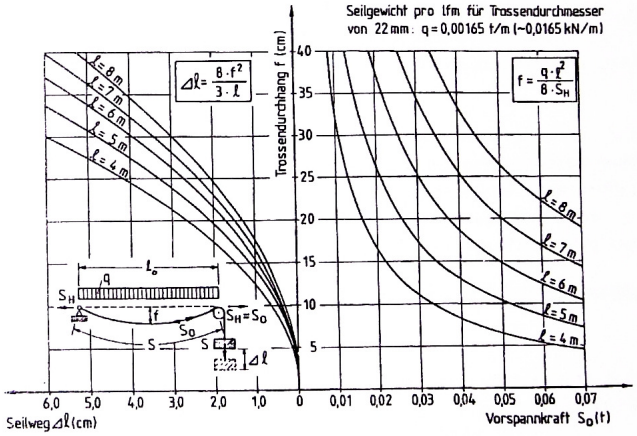


# Hawser strength versus load




Security depends on ship mass?!

# Hawser pretension



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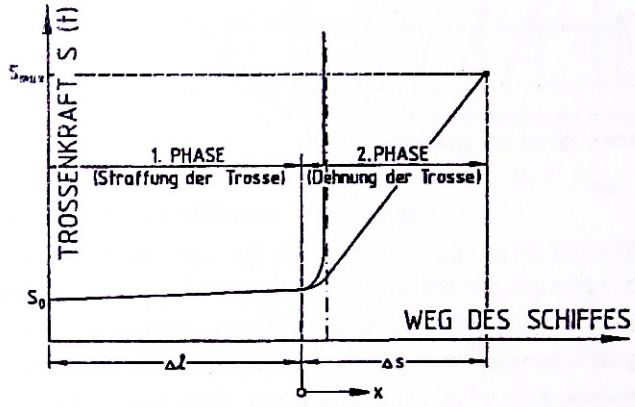
# Reaction force of pretensioned hawsers



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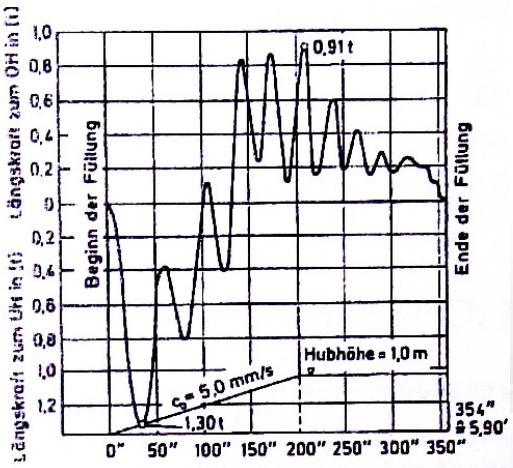
# Typical ship force measurement



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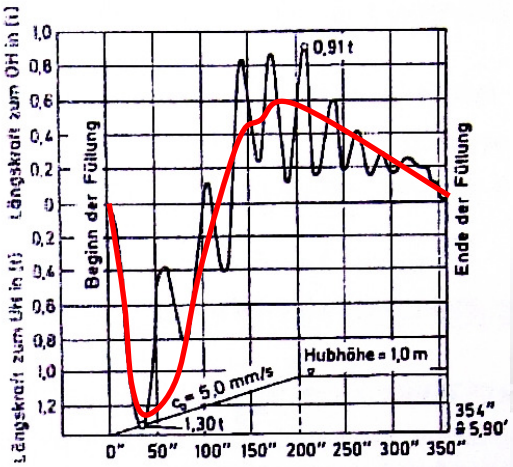
# Decomposition: Filling effects



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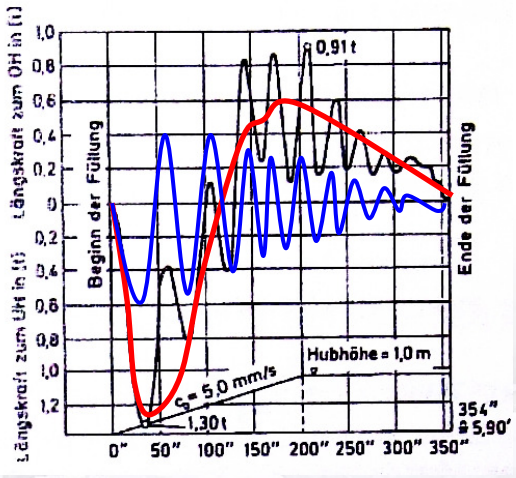
# Decomposition: Sloshing



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# 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…



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## 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)

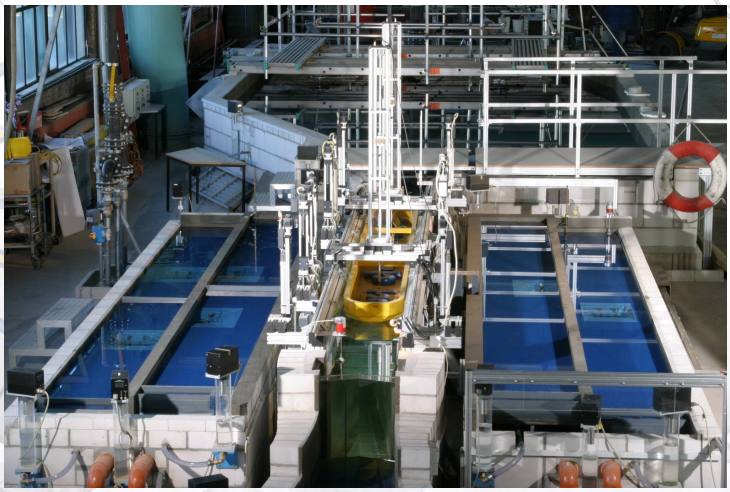
today: ???

*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

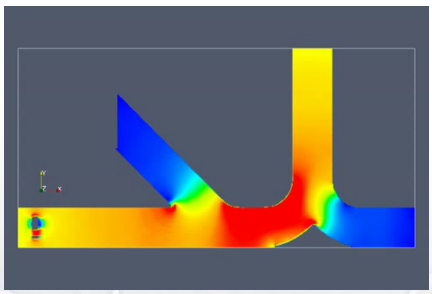


Physical model tests



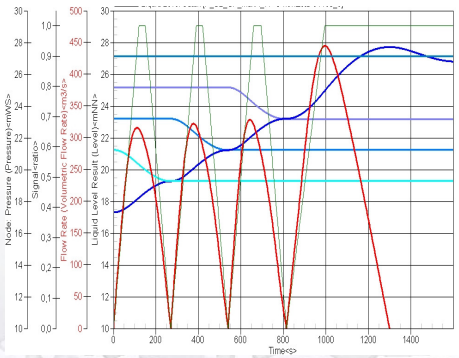
# Numerical modeling strategy

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



# Numerical modeling strategy

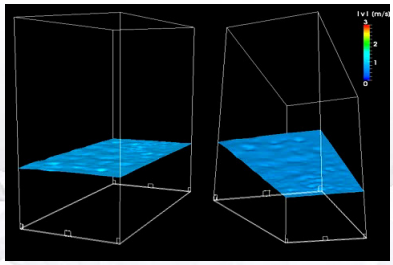
- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex





# 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, …



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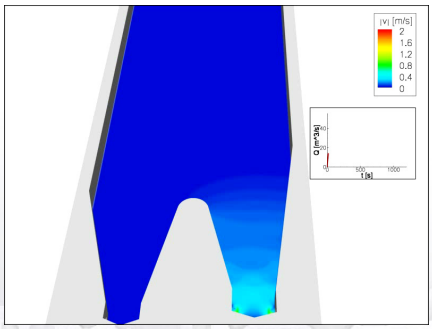
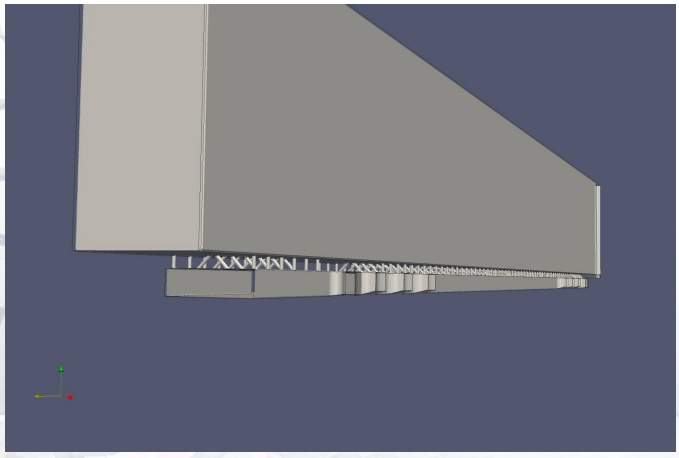
# Numerical modeling strategy

- 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



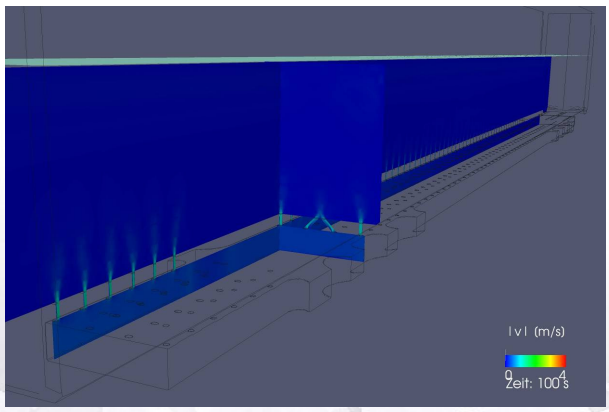



# Evaluation methods



Simplified geometrie modell for 3D-Simulation

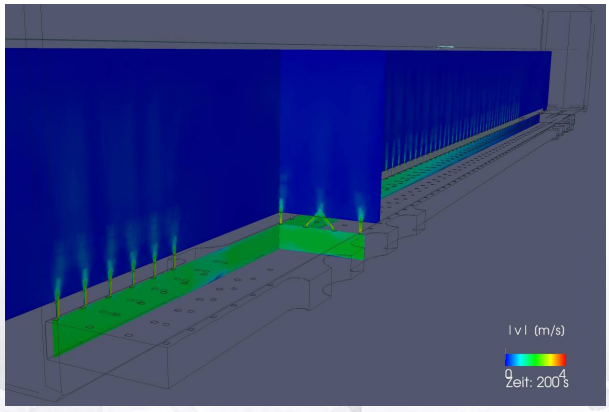
# Evaluation methods




3D-Simulation of filling process



# Evaluation methods




3D-Simulation of filling process

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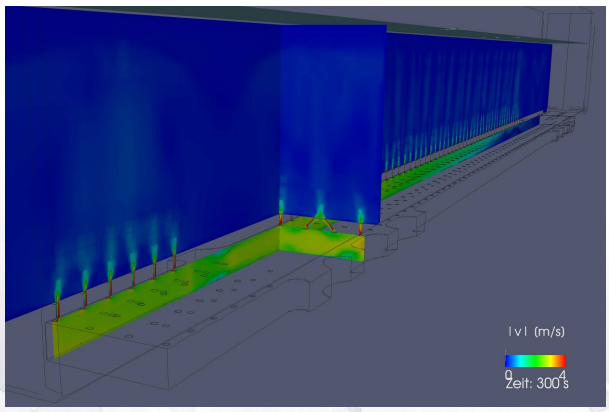
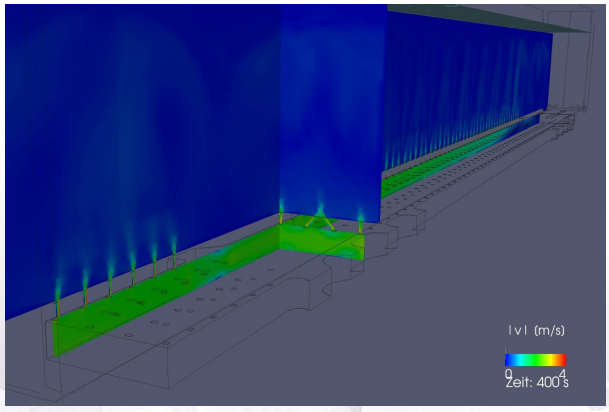



3D-Simulation of filling process



# Evaluation methods




3D-Simulation of filling process

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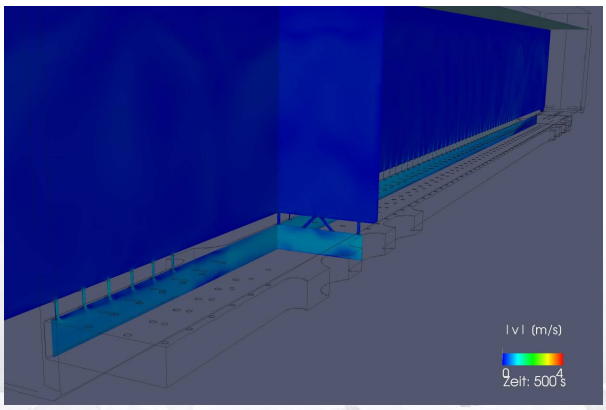


3D-Simulation of filling process



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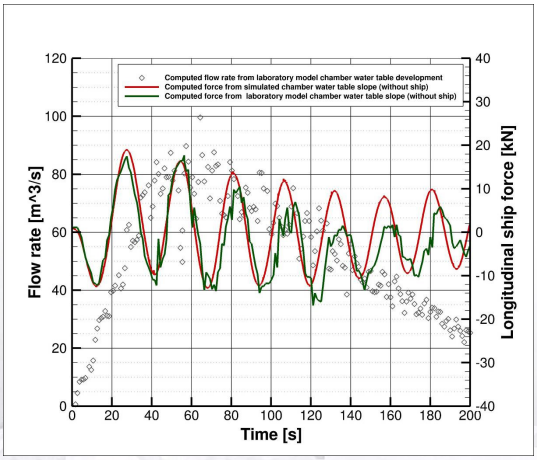
# Evaluation methods




Comparison of numerical and physical model test results



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## 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

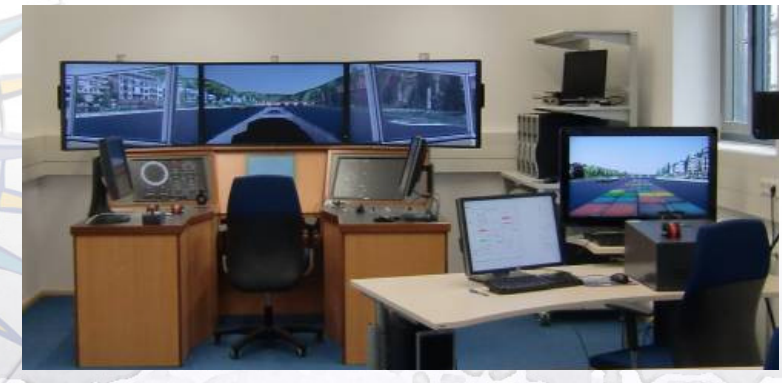
# Guidelines for flow field in the approaches

- 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 …