JOURNAL OF COASTAL AND HYDRAULIC STRUCTURES

Review and rebuttal of the paper

Numerical investigations of ship forces during lockage

Carsten Thorenz and Lydia Schulze

Editor handling the paper: Daniel B. Bung

From: "Daniel Bung" <bung@fh-aachen.de>

To: "Carsten Thorenz" <Carsten.thorenz@baw.de>, "Lydia Schulze" <lydia.schulze@baw.de>

Subject: [JCHS] Editor Decision

Carsten Thorenz, Lydia Schulze:

We have reached a decision regarding your submission to Journal of Coastal and Hydraulic Structures, "Numerical investigations of ship forces during lockage".

Our decision is to accept the paper in its present form.

It is acknowldeged that the authors have made a big effort to properly address all reviewer comments. Both reviewers suggested minor revisions in the first review turn. Another review turn is thus not required.

Congratulations!

From: "Carsten Thorenz" <Carsten.thorenz@baw.de>

To: "Rebekka Kopmann" <rebekka.kopmann@baw.de>, "Daniel Bung" <bung@fh-aachen.de>

Subject: [JCHS] Revised Version Uploaded

Editors:

A revised version of "Numerical investigations of ship forces during lockage" has been uploaded by the author Carsten Thorenz.

Submission URL: https://journals.open.tudelft.nl/jchs/workflow/index/5769/3

Bas Hofland

From: "Daniel Bung" <bung@fh-aachen.de>

To: "Carsten Thorenz" <Carsten.thorenz@baw.de>, "Lydia Schulze" <lydia.schulze@baw.de>

Subject: [JCHS] Editor Decision

Dear Carsten Thorenz, Lydia Schulze:

We have reached a decision regarding your submission to Journal of Coastal and Hydraulic Structures, "Numerical investigations of ship forces during lockage".

We decided to request revisions.

Please revise your paper considering all remarks of the reviewers carefully. Additionally, a table that includes each reviewer's remark and your concerning consideration is needed in an extra file. It should be sorted by reviewers.

Best regards,

Daniel B. Bung

Editor of Journal of Coastal and Hydraulic Structures

Reviewer A: Review of 'Numerical investigations of ship forces during lockage'	Revision
General comments: to analyse the hydrodynamic forces on a ship in a ship lock during levelling, a complex numerical model has been built with three-dimensional CFD, and with a morphing mesh for the moving ship. The model is a test case to determine the ability of the model to predict both the flow through the levelling system and the hydrodynamic forces on the ship. The lock has a longitudinal filling system with a pressure chamber under the lock floor and three water saving basins. The numerical model simulates the first filling of the lock by emptying the lowest water saving basin, which is considered the most difficult stage in the filling process. The results of the numerical simulations are compared to the results of a physical model of the same lock at a scale of 25 to 1. This publication shows the results of a comprehensive study. It is clear that the authors are known with the knowledge developments with regard to the hydraulics of ship locks and lock levelling systems. Also, this 3D CFD simulations with a moving ship in a lock chamber using the 'bidirectional coupling of fluid and structure' is considered state-of-the-art in this field. Indeed, this is high level engineering.	Many thanks for the warm words! Your thorough review was very helpful for us, because it revealed several glitches in the paper and thus made the paper a lot better!

As stated in Section 3.4, which is about 'meshing', the required computational resources are a legitimate argument for not carrying out the usual convergence study. Can be assumed, based on earlier work or grid convergence studies of parts of the system, e.g. only the culvert, that the chosen grid will be adequate for the largest part of the system? (Or refer to Section 4.3.1, which partly answers this question.)	We tried to explain in Section 3.4 , that the mesh was developed in a sequence of "mesh generation" – "simulation" cycles, based on the experience of the modellers how "plausible" hydraulic behaviour should look like. We added a sentence to explain this better and referred to Section 3.4.1 for the local grid convergence test.
Studying the forces on the ship, what could possibly be concluded from the flow distribution over the nozzles in the chamber floor? What is the standard ship position? Do the longitudinal forces originate from the asymmetric position of the ship in the longitudinal direction?	We explained the geometric properties in much more detail now, thanks for the suggestion.
The numerical model shows new possibilities. However, what are the limitations of the mesh deformation?	Thanks for the proposal We added some explanations about that.
Would it be possible to simplify the approach by, firstly, design the longitudinal culvert system, including water saving basins, culverts, pressure chamber and nozzles, applying a constant water level in the lock chamber? And, secondly, use the result of the first step as an inflow boundary condition/flow distribution at the lock floor for the lock model with deforming mesh and moving ship?	Yes, this can be done to optimize the "general hydraulic performance" of the components and can be helpful to gain understanding for the system. Actually, we did "component simulations" in earlier stages of the project to optimize it. But for the system with ship in the chamber the benefit of cutting off the culverts is small, because most effort is necessary for "nozzles + chamber + moving ship" anyhow. Do attach the culvert and savings basins to that, doesn't change much in terms of computational effort but reduces (!) the modelling complexity as the model is "all in one" then with no additional tricks needed.
Paper title: use capital letters.	Ok. Implemented changes as suggested

Abstract, Line 16: '…knowledge **of** physical understanding and…'.	Ok. Implemented changes as suggested
Abstract, Line 92: '…at a scale of 1:25…'.	Ok. Implemented changes as suggested
Line 19: '…forces **becomes** more difficult.'	Ok. Implemented changes as suggested
Line 24: for your interest. In 2015 in The Netherlands effort has been put into the determination of new force criteria for inland navigation ships in ship locks. The method consisted of a coupling of Lockfill (1D numerical model to describe the longitudinal hydrodynamic force on a ship during levelling) and SCHAT (SCHip-Aan-Tros, massspring-model to determine the forces in the mooring lines, and the displacements and velocities of the ship, using time series of the hydrodynamic force and the water levels as input). First, a database was filled using MONTE CARLO, with a large number of combinations of 14 different parameters (ship class, mooring line material, lock chamber size, total head, filling, emptying, pretension etc.). In total, the database contained 26.000 combinations of different parameter values. Then, the coupled LockfillSCHAT simulations were carried out to determine the force criterion for each case. These results have been converted to general criteria.	This is a helpful reminder, as we heard about it before and then forgot again. We'll contact the colleagues for an exchange on the updates on this.

Line 52: '… a fixed threshold…'	Ok. Implemented changes as suggested
Line 60: for your interest: 'Effect of Density Differences on the Forces Acting on a Moored Vessel While Operating Navigation Locks,' Nogueira et al., Journal of Hydraulic Engineering, ASCE (2018).	Thanks, that's interesting for further reading!
General: error in the footer.	This is due to the anonymization and will be corrected in the final version

Line 83: '…though the shape of the transient force curve was favourable…' Explain.	Thanks. We exchanged "favourable" by "similar" and explained :" The temporal development of the force caused by an initial surge wave followed by a change of sign and subsequent forces into the opposite direction was reproduced."
Line 92: '…that **received** only little attention in the past.'	Ok. Implemented changes as suggested
Equation 5: where does T stand for?	Vectorial notation for "transposed"
Line 156: '…a minor role **in** the considered case study.'	Ok. Implemented changes as suggested

Line 260: '…if the relevant flow patterns could be observed in the simulations.' Have different mesh resolutions been considered to work towards an acceptable accuracy, e.g. for the more critical parts of the system?	Yes. We added sentences to clarify this.
Line 272, Figure 3: what is the mesh resolution at the water surface in the lock chamber?	It was not easy to show all feature in a single plot. The resolution is 0.0625 m. We change the figure to show the water surface area.
Line 294-300: can be assumed, based on earlier work or grid convergence studies of parts of the system, e.g. only the culvert, that the chosen grid will be adequate for the largest part of the system or is this uncertain?	We added some explanations. But some uncertainty remains, because these local studies are not the same as a "complete" refinement.
Line 304: '…of 11.27 m **relative** to the lock chamber **floor**.'	Ok. Implemented changes as suggested
General: mention early that parameter values in the text are prototype values.	We added a further remark on that at beginning of Section 2.

Line 417: '…five pressure difference sensors are installed inside the pressure chamber.' How reliable are these measurements for determining the water level differences in the lock chamber accurately, as these may be influenced by the flow through and head losses over the nozzles?	This was an error. The sensors are connected to the lock chamber. Thanks for the question!
Line 420: '…until it **is fully open** at 40 s after the start.'	Ok. Implemented changes as suggested
Line 425: as forces will be mainly determined by water level differences over the ship, why are the water levels not compared? Considering the maximum longitudinal force that has been measured, how does this compare to the measured water level difference? (Now, the answer is in Line 442.)	Actually we thought about it, but then we decided to focus on "the most important" which is the force. We didn't want to overload the paper with more information, as it is already pretty long.
Line 478: Fehler! Verweisquelle konnte nicht gefunden werden.	Ok. Inserted correct link to Figure 7.
Line 483: estimating the mass of the water displacement of the ship at 36.000 kN, the relative force is about 45/36.000*1000 = 1,25‰. The allowable force for this ship according to our criterion is about 1‰. It seems that the filling system in the lock is symmetric. Do these forces originate from the asymmetric position of the ship, which in this case is closer to the upper gate?	As stated in the text, the chosen valve schedule does not resemble the prototype valve schedule. Thus, the forces would be too high for the prototype. We added a sentence about the asymmetry, thanks..
Line 507: the development of the transversal forces may depend on the hull shape of ship. Is the ship hull in both models the same?	The hull is a typical self propelled vessel and the same in both models. If not, we should have stated it …
Line 511: Fehler! Verweisquelle konnte nicht gefunden werden.	Corrected.

Line 514: '…because those effects would occur with or shortly after the highest flowrates.' Using a through-the-head filling system this is maximum just before the maximum flow rate, when the combination of filling rate and flow velocity (proportional to the momentum of the flow) is maximum.	In this system the maximum momentum is reached at peak flow rate, because the nozzle diameter is fixed and thus maximum flowrate and maximum velocity coincide. So the maximum force from jets was expected at that time or shortly after.
Line 515: 'Instead, we conclude that the maximum force corresponds to the rate of increase of the flow rate.' Could the maximum force be the sum of two force components?	It actually is always a combination. But the jet effects are expected later, and at a later time the forces go down to ~zero, even for still high flow rates. So . the jet effects must be small in comparison.
Line 517: '…a slower opening of the valve decreases the maximum of the longitudinal forces much more than it decreases the maximum of the flow rate.' The maximum force due to the momentum decrease may not be proportional to the flow rate.	The momentum decrease is not a governing factor, because the main flow direction in the lock chamber is vertical.
Line 520: '…the assumption that the transversal forces are triggered by jet effects…' Can this be explained by the asymmetric position of the vessel and/or an the asymmetric filling of the chamber, and the water that is partly pressed in the narrow space between the ship and the chamber wall, resulting in a higher water level in this space compared to the other side of the ship? Has the flow distribution over the nozzles been determined?	Yes, we think it is triggered by the asymmetric position of the ship. We have more information on the position. We think that not the narrow space, but the asymmetric position causes the jets to touch the vessels differently on left and right side of the vessel. The flow distribution through the nozzles is astonishingly even. This leads to no usable insight.
Line 536: '…a slice 0.2 m above the sill.' The floor of the pressure chamber.	Thanks, corrected.
Line 574: what follows from the comparison with the physical model?	This question is not clear, sorry.
Line 577: 'As mentioned in section 3.4…' **S**ection 3.4.	Thanks, corrected.

Line 588: '…in the pressure chamber**,** the pressure…'	Thanks, corrected.
Line 589: how does the result for Ux=0 relate to the loss coefficients found in literature (maximum loss coefficient » 0,6 (inlet) + 1 (outlet) = 1,6, which is close to the numerical model)?	For Ux=0, the situation is comparable, but not exactly the same as the combination from the literature. In the literature, it is assumed that the two components "inlet" and "outlet" are connected to very long tubes, which is not the case here. Anyhow, we're happy to be so close to the textbook values.
Line 590: place figure title below figure.	This will be made in final formatting.
Line 595: 'Thus, a basis grid size of 0.5 m with 22 cells…' 0.5 m while the diameter of the nozzles is 0.3 m?	This was an error due to remaining text from a prior version. Thanks.
Line 613: what is the ship standard position?	We explained the position in more detail now in section 3.10.
Line 728: '…the derived numerical model is good enough to have predictive capabilities.' The numerical model shows new possibilities. However, what are the limitations of the mesh deformation? Is there a maximum to the head that can be levelled?	We added further considerations about the mesh deformation approach in section 3.4. Yes, there are limits.
Line 747: add T to notation.	Thanks, corrected
Line 783: Nogueira.	Thanks, corrected

Reviewer B: Review of 'Numerical investigations of ship forces during lockage'	Revision
General appreciation: To the best of my knowledge, this paper is the first one to present and validate a numerical prediction of ship forces during lock levelling, based on a 3D CFD model of the lock filling-emptying system, the lock chamber and the ship motion (with Fluid-Structure-Interaction). It is an important step forward in the hydraulic design of navigation locks. The paper is well written and well-structured. I can strongly recommend its publication, after a minor revision, based on the following remarks and suggestions.	Thank you for your warm words! Your thorough review revealed several weak points, where we should have been more clear. So, thank you for making this paper better!
L. 42-44: why no direct impact force of jet on ship's hull (bow or stern) is mentioned as a possible source for longitudinal ship forces ?	… because Krey (1914) thought that jets on the hull should be avoided and thus didn't mention it. We added a sentence about jets for clarification.
L. 94, L. 283-284: please add some more details of the pressure chamber filling system, in particular the distribution of the nozzles in the lock chamber floor (spacing in longitudinal and lateral direction ? over full length of lock or concentrated in the middle part ? etc.); best to add a sketch	We added a significant number of sizes to clarify this.
L. 399-400: please add the position of the ship in lateral and longitudinal direction, both in the physical model and in the numerical model ; this information is essential to the reader	Thank you for this important suggestion.
L. 407-408: is pitching possible ? for clarity, better explicitly mention the degrees of freedom which are still possible	In the new version we explicitly stated the possible movements.
L. 416: "along the longitudinal axis of the chamber" ➔ I assume the lock chamber is meant; if so, then please replace "chamber" "by lock chamber"	Thank you for the comment, enhanced.
L. 417: are these sensors installed along the longitudinal symmetry axis of the lock chamber ?	Enhanced and corrected the text.
L. 417: is the position of the ship not recorded ?	Unfortunately, no.

L. 444: please clarify a bit how the flowrates are computed from the 5 pressure sensor time series (just an arithmetic average ? moving average ?)	Thank you for the comment, we enhanced the text with a more detailed description.

L. 616: it is not clear to me how reader can notice in Figure 11 the pressure drawdown; please clarify	The jets touch the vessel asymmetrically, resulting in a pressure drawdown from the jet that creeps around the ship bilge corner. We enhanced the text to explain this. Actually this helped us to find an error in Figure 14 (legend was wrong).

Culverts connecting water saving basin and lock chamber: please improve the clarity in the paper as to the position and use of the culvert valves. On Figure 1, the text “culvert with valve” (i.e. singular form “valve”) and the accompanying arrow points to a boxshaped opening, which is preceded by one slot upstream and three slots downstream. The latter 4 slots may then be interpreted by the reader as recesses for bulk heads (maintenance). This impression then suggests that actually only one valve is present, ahead of the “trifurcation”. This impression is confirmed by Figure 4, where again “valve” is used in singular form. In Figure 5, however, 3 drives (plural form) for valve operation appears, which suggests that each subculvert in the trifurcation has its own valve. The latter impression is confirmed by Figure 9 and Figure 10, where apparently only the middle subculvert is used for filling the lock chamber. Finally, L. 397 in the text reveals that 6 valves were installed inside the (two) culverts connecting the water saving basin to the lock chamber. It would be nice to clarify this issue in the paper.	Important clarification: There is no “trifurcation”. For explanation from Chapter 2: “The three lateral saving basins are connected to the pressure chamber via lateral culverts of smoothly varying rectangular shape. Each saving basin has two of these connecting culverts. A vertical lifting valve in each culvert allows the controlled filling operation from the saving basins into the pressure chamber. “ So, in total there six valves for the three basins with one valve in each culvert. But in this comparison study, we used only the lowest basin with its two culverts and valves. We added some more text in Section 2. We added further text to explain the slots: “Attached to each culvert, there are three vertical shafts. The middle shaft contains the valve. The other two shafts serve for mounting the valve bulkheads. Towards the pressure chamber you see additional culvert stubs with one vertical shaft each, one on the left and on the right of each connected culvert. These are the remnants of the cut-off culverts leading to the cut-off water saving basins, which are not regarded in this study” In Figure 4, there is only one valve visible. Thus “singular”. Figure 5 shows the physical model, which has six valves in total. We changed the arrows to the ones used in this comparison. Maybe it’s clearer now. Figures 9 and 10 again show the stubs of the cut-off culverts leading to the cut-off basins.

	L 397 describes the physical model, which contains all basins and all valves. Thus six in six culverts. For this study: Two valves in two culverts were actually used.
Now the paper focuses only on predicting forces on the ship. As a substitute for (the hydrostatic component of) ship forces, water surface slopes are often adopted in the hydraulic literature on locks. No information is given in the present version of the paper as to the predictive qualities of the numerical model for the end-to-end longitudinal water surface slopes in presence of the ship. Also in absence of the ship, it could be interesting to show the predictive capabilities for the end-to-end slopes.	We completely agree that this would be an interesting investigation. But looking at the scope of the paper, the extend the paper already has and at the necessary additional tasks (the required simulations "without ship") we think this would require another publication.
General remark: please harmonize the use of a comma between the author(s) and the year in bibliographical references in the text	Thank you for the comment, corrected
Abstract: replace "showed" by "shows	Thank you for the comment, corrected
L. 13: replace "To guarantee adherence to the force limitation is crucial" by "It is crucial to limit these forces"	Thank you for the comment, enhanced.
L. 13: replace "life" by "life, ships and lock infrastructure"	Thank you for the comment, enhanced.
L. 17: replace "numerical" by "advanced numerical"'	Thank you for the comment, we changed the whole sentence..
L. 20: replace "In literature" by "In the literature"	Thank you for the comment, corrected.
L. 52: replace "fix" by "fixed"	Thank you for the comment, corrected.
L. 74: Some caution is needed when using the term "hybrid modelling", since often this term is used when adopting both numerical and physical modelling. See e.g. the following references:	Agree. Clarified that "hybrid modeling" is the "mixing" of differing modelling strategies: Numerical + physical or 1D-numerical with 3D or ...
L. 75: Thorenz (2010) is not in list of references.	Thank you for the comment, corrected.
L. 75: please also add the following refer-ence: Menéndez, A. N., Badano, N. D., Lecertúa, E. A., Gerbec, M. S., Re, F., & Re, M. (2010). Computational Fluid Dynamics(CFD) for Hydraulic Design of the Panama Canal Third Set of Locks.	We added this interesting reference.

Mecánica Computacional, 29(36), 3683-3697.	
L. 143-144: replace “to describe the phase transport” by “to capture the interface between air and water”	Changed to “additional scalar transport equation to describe the transport of the distribution of air and water” in order to avoid possibly misleading term “interface capturing”
L. 152 and elsewhere in paper: replace “viscosity” by “dynamic viscosity”	Changed in most places.

L. 166: It is not clear to me what is meant with “When the spatial discretization is appropriate”	Changed this and the prior sentence: “In hydraulic engineering the direct numerical simulation (DNS) of the turbulent flow behaviour is rarely feasible for practical purposes due to the necessary extremely fine computational grids. With a substantially coarser spatial discretization, the Large Eddy Simulation (LES) approach can be applied.”
L. 187: which pressure: the modified pressure ?	No, the “real” pressure.
L. 191 and following: not sure it is really needed to explicitly add eqs. 8 and 9 in the paper ; I believe the text suffices to state the message	Agreed. We deleted the equations.
L. 200: reader may wonder “what about contact forces between ship and lock chamber walls”	Added a sentence about external forces.
L. 242: 30s valve opening time is mentioned, while L. 420 mentions valves are fully open at 40 s after start ; for the reader it may be more clear to define as t = 0 s the end of the initial period of 10 s during which the valves stay close	We prefer to stick to the current time line. The initial 10 s “calm” period is a necessar part of the experiment and thus the timeli should start at the beginning of the experiment with t=0s and not with t=-10s. The valve opening (beginning at t=10s) is one event on the timeline. We added a sentence to clarify the valve schedule and deleted the “30s” to avoid confusion.
L. 292: replace “necessity” by “necessary”	Thank you for the comment, corrected.
L. 331: replace “dissipation Ω” by “specific dissipation rate ω”	Eliminated the symbols for k and omega, as they are not needed and corrected “specific dissipation rate”
L. 361: for readability, add number of days/hours after 268000 s	Added “more than three days”.

L. 381: not sure that “project requirements” is clear to the reader, since the whole paper does not focus on a specific project…	We explain now that the model was not built for the purpose of this study.
L. 415: is not clear to me ; please clarify	This was misleading, we changed the text.
L. 416: add “lock” before “chamber”	Thank you for the comment, corrected.
L. 444: add “lock” before “chamber”	Thank you for the comment, corrected.
L. 467: replace “if” by “whether”	Thank you for the comment, corrected.
L. 478 and L. 511: cross-reference to Figure 7 is not correct	Thank you for the comment, corrected.
L. 537: erase “an” in front of “upwelling”	Thank you for the comment, corrected.
L. 550: replace “to” by “in”	Thank you for the comment, corrected.
Figure 11: Now the figure does not answer the question of the reader whether the ship is positioned centric over the width of the lock chamber, or not; maybe show the full width	Thanks. We changed the viewport of the figure a little, so that the chamber wall is visible. Furthermore we added a sentence which
of the lock chamber ? Moreover, the attention of the reader is not drawn to the fact that Figure 11 clearly shows that the distance from the nearest nozzles to the left and right sidewalls of the pressure chambers are different.	explains the asymmetry and added text about the ship position. This impression is misleading. This is only the case in this section, because the slice cuts through the “trumpet” shaped outlet of the culvert. Added text to explain it.
L. 588: add comma after “chamber”	Thank you for the comment, corrected.
L. 644-645: “exact ship position is difficult to maintain” sounds a bit strange, since the ship continuously moves during the lock filling	It was clarified that we talk about the horizontal position.
L. 654 and following: Modeller is referred to by “he/his”; maybe better to reformulate in a gender-neutral way	Thank you for the comment, corrected.
Table with notation: Surface normal vector is dimensionless	Thank you for the comment, corrected.
L. 729: “correct viscosity”, do you refer here to the correct temperature or the correct value for the prototype situation ?	We thought about the prototype. Corrected.
L. 763: replace “2005” by “2015”	Thank you for the comment, corrected.