Notes on two experiments for validation of SPH: dam-break and tuned sloshing damper

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Iberian SPH 2015

POLITÉCNICA

outline

1. Motivation & background
2. Dam-break experiments
3. Canonical coupled sloshing
4. Final remarks

1. Motivation & background

Verification assessment determines if the programming and computational implementation of the conceptual model is correct. It examines the mathematics in the models through comparison to exact analytical results. Verification assessment examines for computer programming errors.

Validation assessment determines if the computational simulation agrees with physical reality. It examines the science in the models through comparison to experimental results.

NPARC Alliance CFD Verification and Validation site

more concise.....

Verification is the process of determining that a model implementation accurately represents the developer’s conceptual description of the model and the solution to the model.

Validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model.

1998 AIAA Guide, Ref. [1] (on computational models)

Do we clearly distinguish these aspects when looking at results from our SPH sims and compare them with.................................

other simulations, analytical results, experiments?

My aim with this presentation is to critically discuss two sets of experimental results (in which i was involved) in order to increase their usability for SPH code validations..

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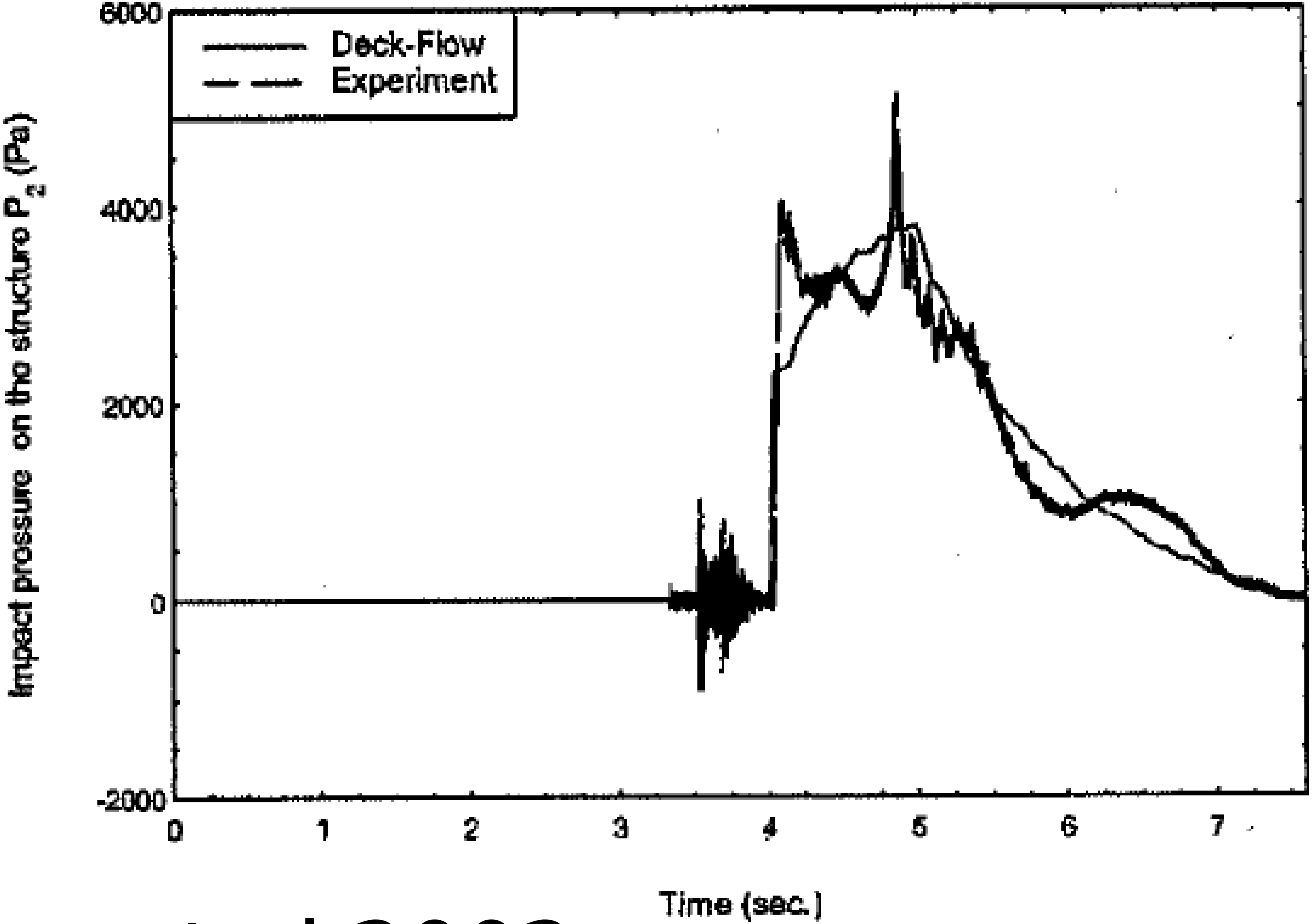
Famous dam-break of Zhou et al 1999 (in journal by Lee et al 2002) revisited in a campaign in spring-summer 2012 in Madrid with Libor…., leading to:

Lobovský, L., Botia-Vera, E., Castellana, F., Mas-Soler, J., and Souto-Iglesias, A. (2014). Experimental investigation of dynamic pressure loads during dam break. Journal of Fluids and Structures, 48:407-434.

http://canal.etsin.upm.es/papers/lobovskyetaljfs2014/VIDEOS/Fig06_test_91.m4v

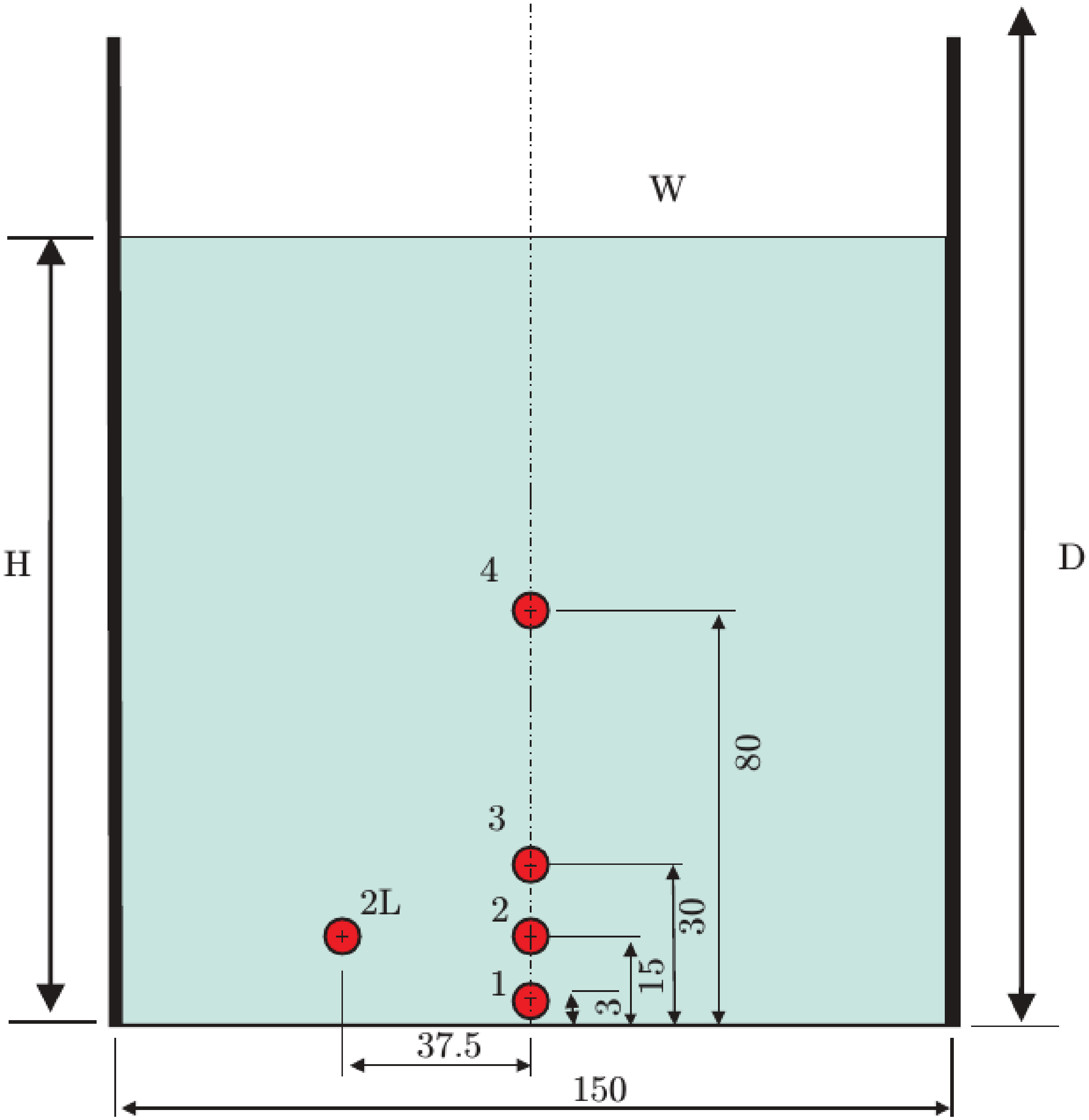
Issues with Zhou et al 1999

1) No repeatability analysis.
2) Huge load cells (9 cm diameter)
3) peak pressure is due to back flow

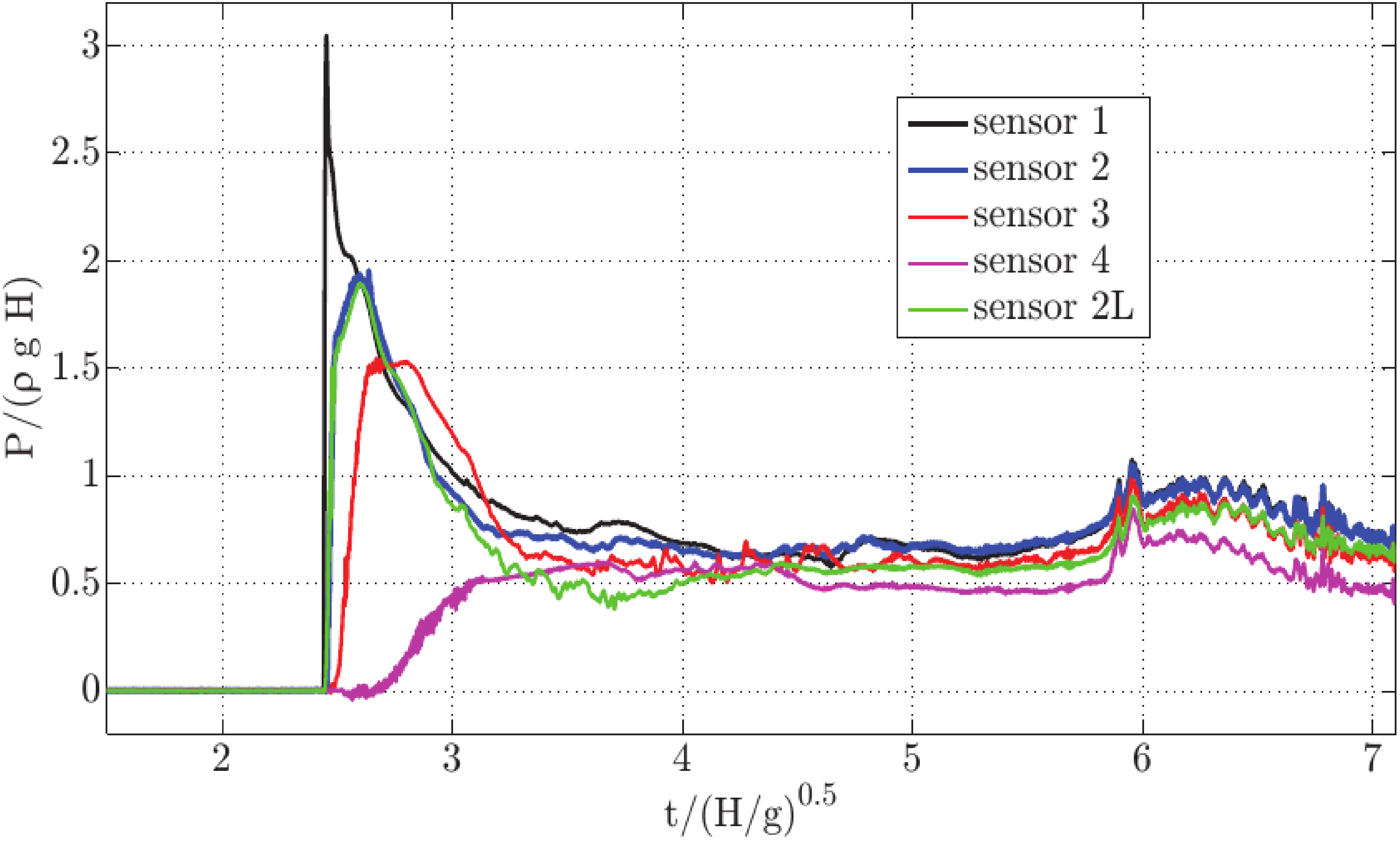


Lee et al 2002

http://canal.etsin.upm.es/papers/lobovskyetaljfs2014/VIDEOS/Fig13_rail_video.m4v http://canal.etsin.upm.es/papers/lobovskyetaljfs2014/VIDEOS/Fig09_test_101.m4v



Let's see registers from one exp...


3
2.5
2
1.5
1
0.5
0
P/(ρ g H)
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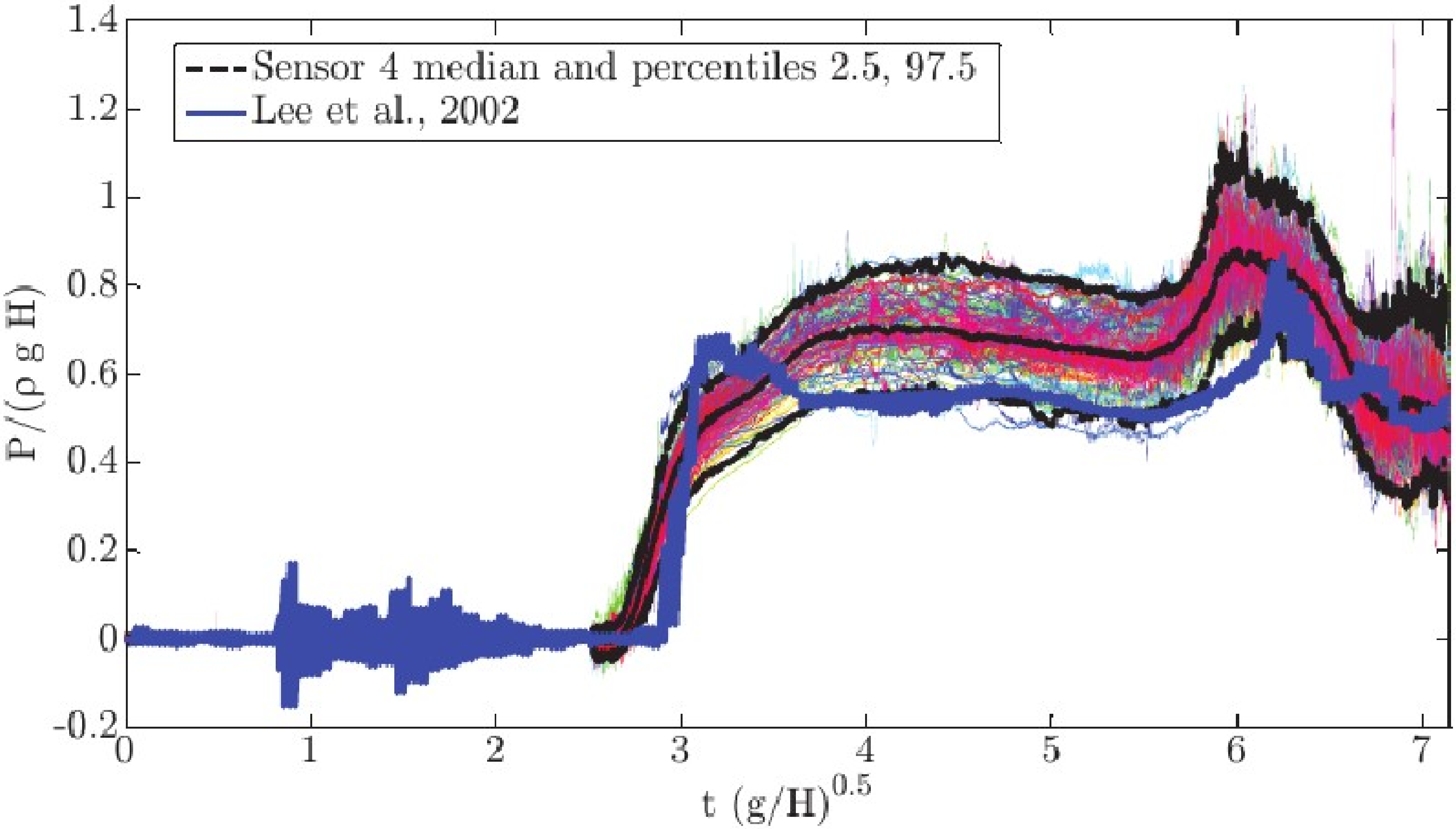
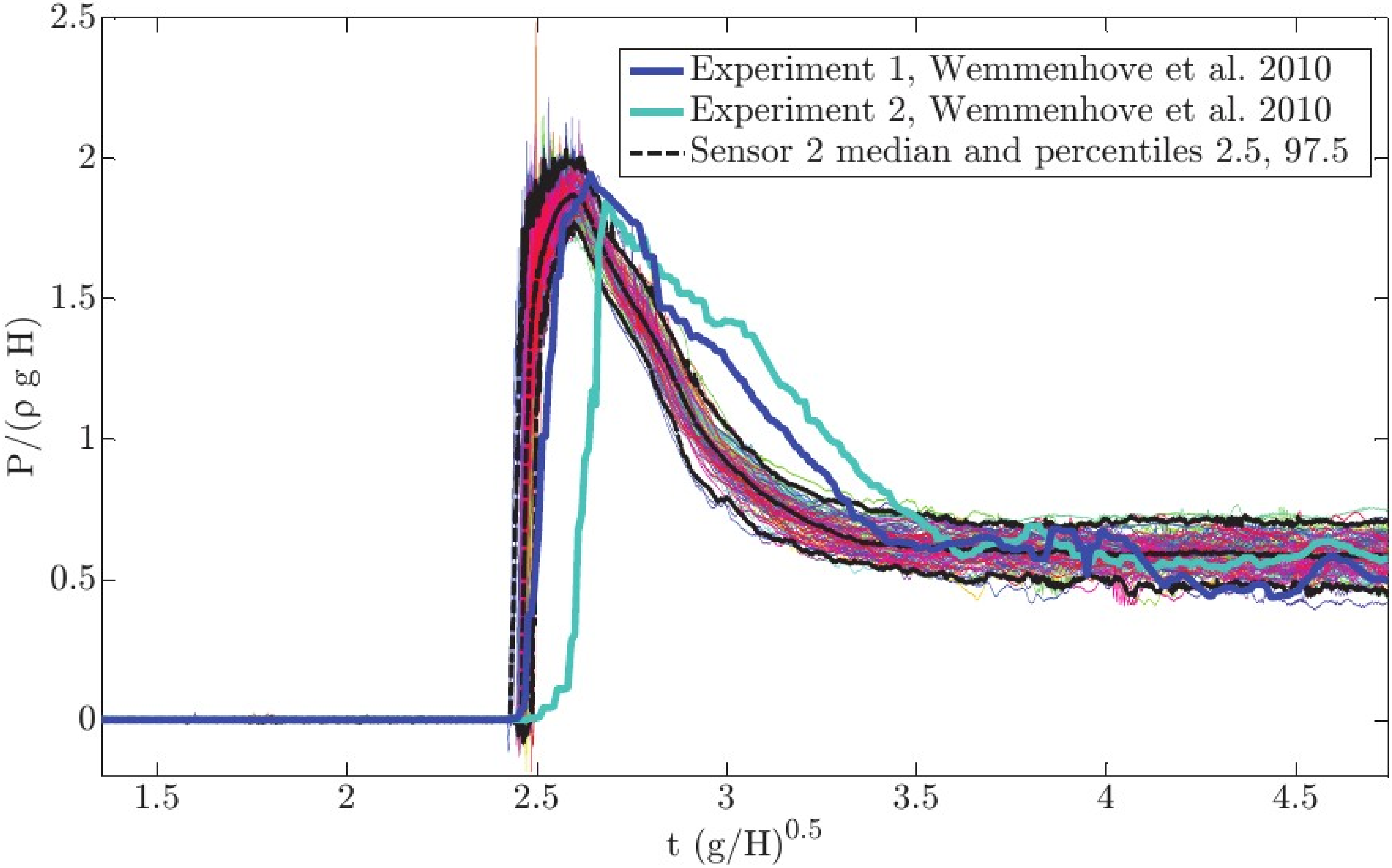
7
t/(H/g)^0.5
sensor 1
sensor 2
sensor 3
sensor 4
sensor 2L



Lee et al peak is in back flow with large confidence interval.



lower sensors display larger repeatability...

you can plug your own data in the fig. files provided..

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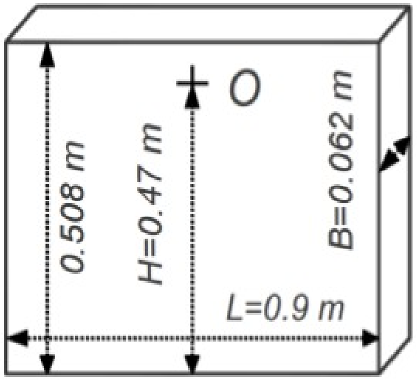
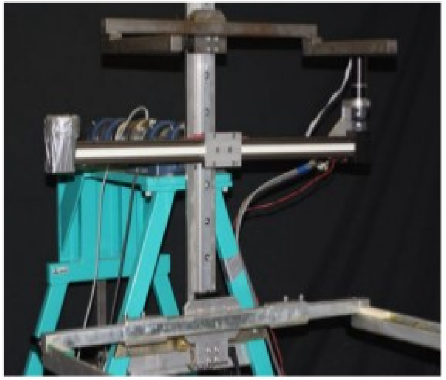
A SDOF dynamical system, mimicking sloshing+roll motion, which allows to "eliminate" uncertainties from forcing term, external damping, etc.. and obtain forces and energy transfers from kinematics is devised, built, tested and analysed (Bulian et al, 2010, Bouscasse et al, 2014a,b, SPHERIC benchmark number 9)

Comparison with empty tank

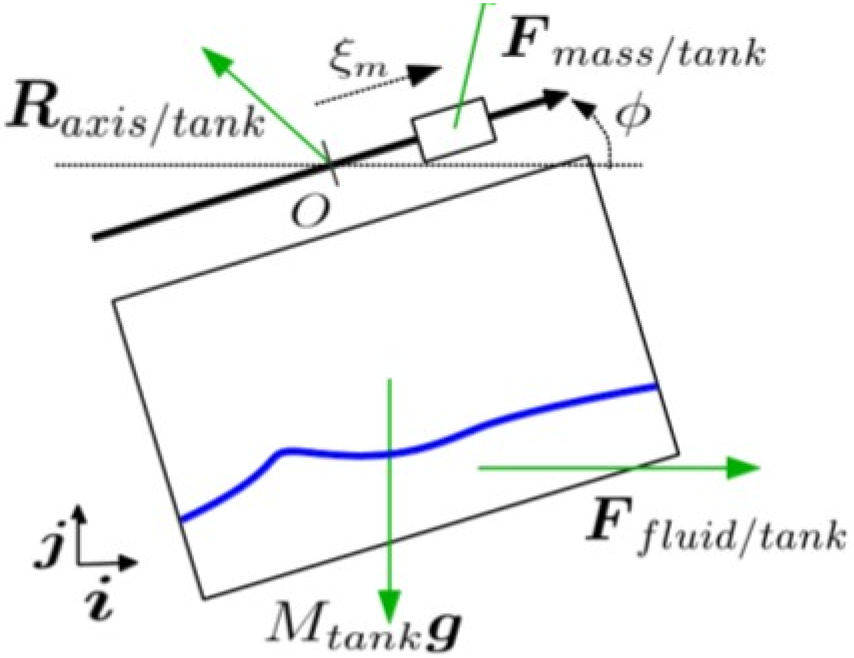
Coupled dynamical system

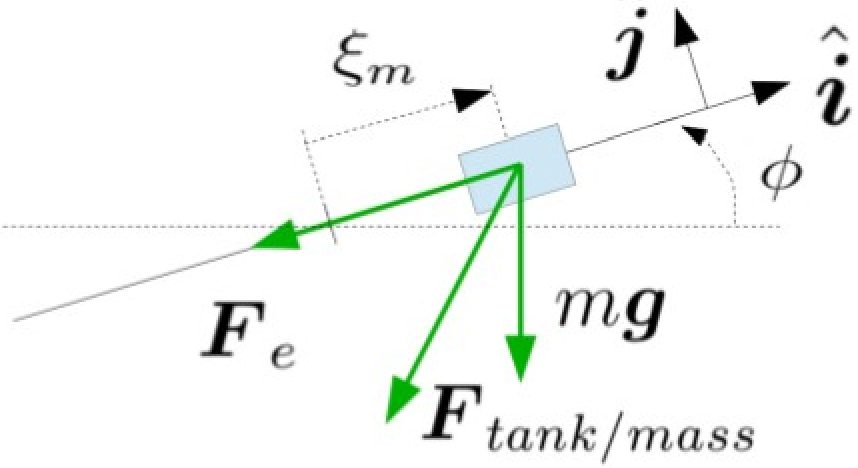
- The shifting mass
- The moving part of the sloshing rig
- The fluid





$$\xi_m(t) = A_m \sin(2\pi t/T)$$





Equations

Torque created by the sliding mass on the tank

$$\boldsymbol{M}_{mass/tank} = \xi_m \hat{\boldsymbol{i}} \times \boldsymbol{F}_{mass/tank} \cdot \boldsymbol{k} =$$

$$= -m\xi_m g\cos(\phi) - m(2\xi_m\dot{\xi}_m\dot{\phi} + \xi_m^2\ddot{\phi}) \boxed{\approx -mgA_m \sin(\omega t)}$$

Friction contribution:

$$\boldsymbol{M}_{friction} = -B_\phi\dot{\phi} - K_{df}\,\mathrm{sgn}(\dot{\phi})$$

Angular momentum equation (for simulation):

$$I_0\ddot{\phi} - gS_g\sin(\phi) - M_{friction} - M_{fluid/tank} = M_{mass/tank}$$

Equations

Torque fluid tank (from experiments) :

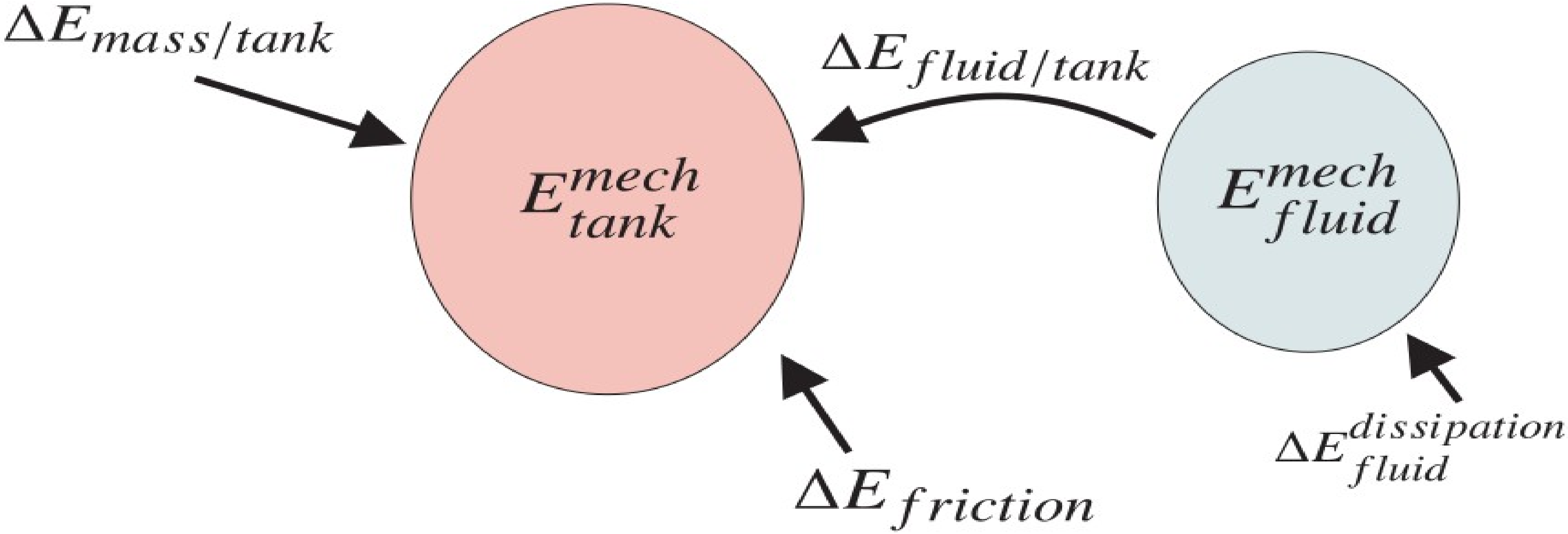
$$
\begin{aligned}
M_{fluid/tank} &= I_0\ddot{\phi} - gS_g\sin(\phi) + B_{\phi}\dot{\phi} + K_{df}\mathrm{sgn}(\dot{\phi}) + \\
&+ m\xi_m g cos(\phi) + m(2\xi_m\dot{\xi}_m\dot{\phi} + \xi_m^2\ddot{\phi})
\end{aligned}
$$

You can get the fluid loads from kinematics!!!!!!!

Energy balances (1)

- Multiplying the angular momentum equation by angular velocity
- Integrating over a period

$$\left[E_{tank}^{mech}\right]_t^{t+T} - \Delta E_{friction} - \Delta E_{fluid/tank} = \Delta E_{mass/tank}$$



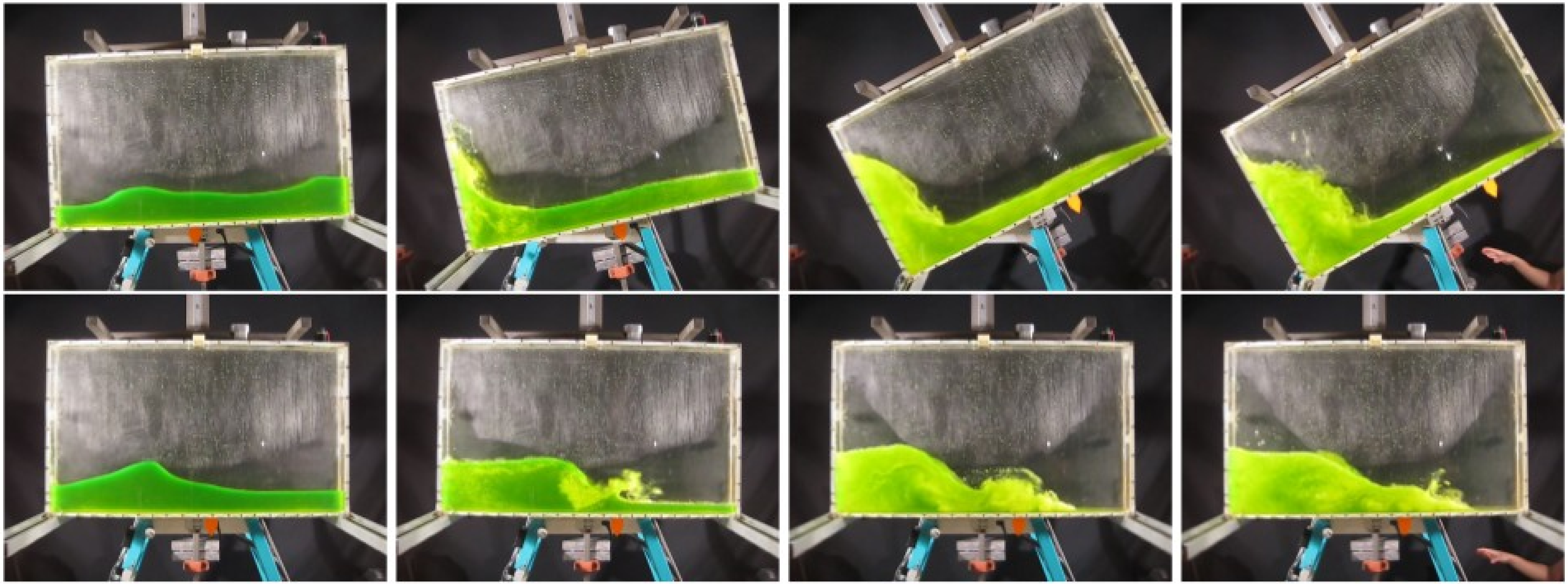
Energy balance (2)

In time periodic state (steady-state) the value of the dissipation can be obtained from experiments

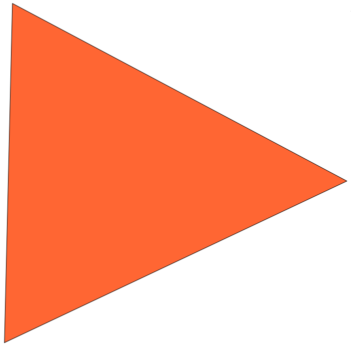
$$\xcancel{[E_{tank}^{mech}]_t^{t+T}} + \xcancel{[E_{fluid}^{mech}]_t^{t+T}} - \boxed{\Delta E_{friction}} - \underset{\underset{\text{Deduced}}{\uparrow}}{\Delta E_{fluid}^{dissipation}} = \boxed{\Delta E_{mass/tank}}$$

Experiments

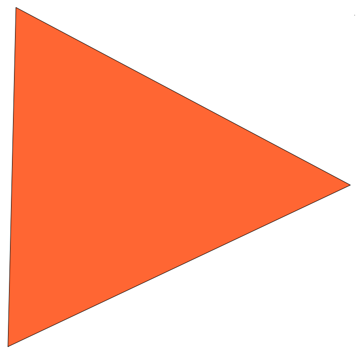
$$\omega^{\text{mass}} := \omega_1^{\text{fluid}} := \omega_1^{\text{tank}}$$



Am=0.05 m



Am=0.15 cm



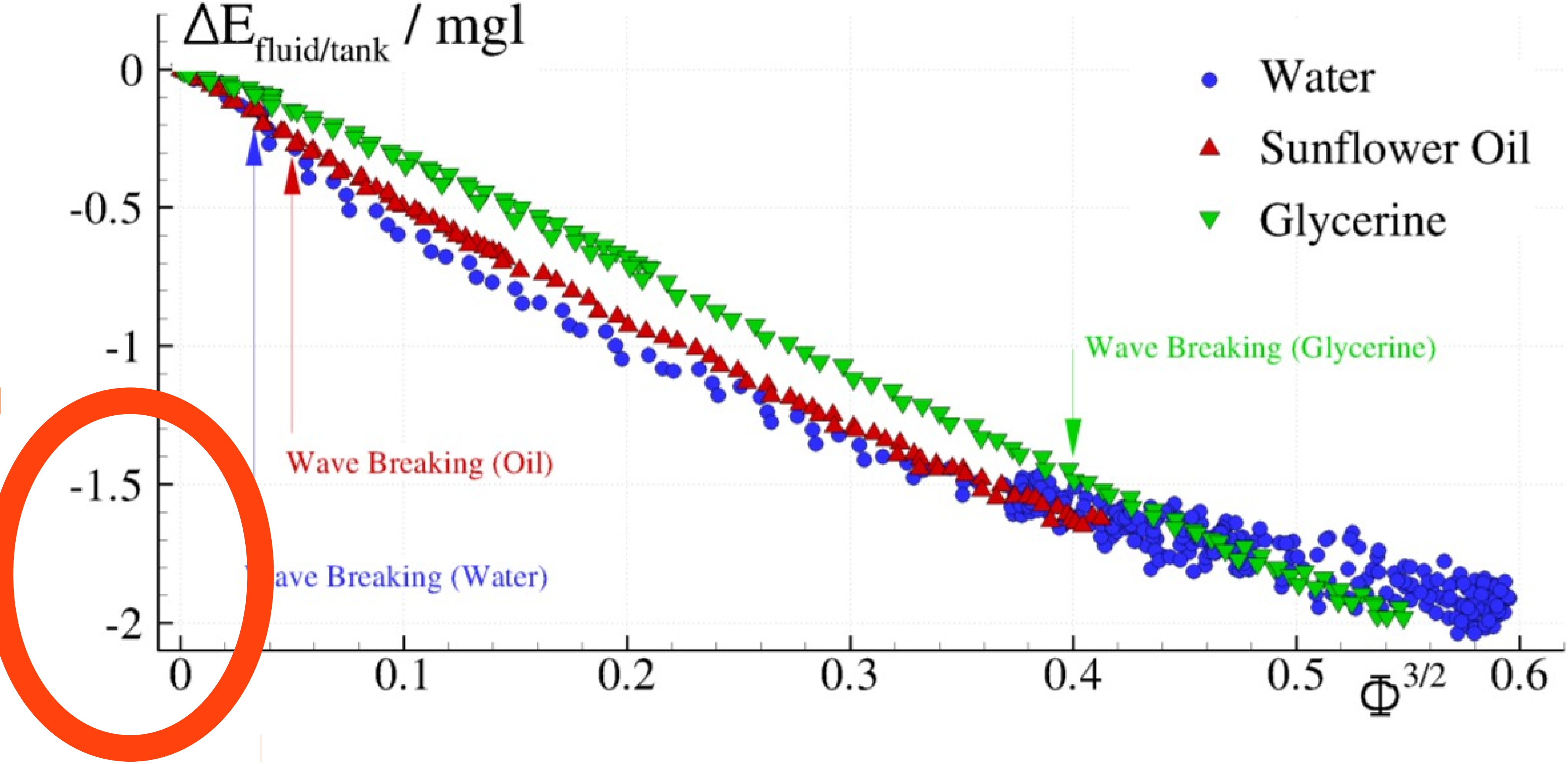
Theoretical analysis (main outcomes)

$$\Delta E_{fluid}^{dissipation} \propto \Phi^{(3/2)}$$

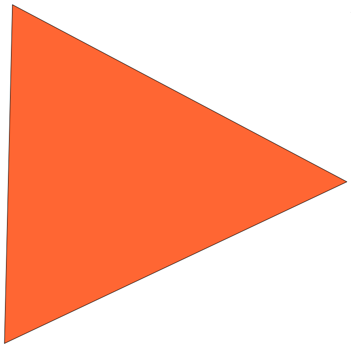
$$\frac{\Delta E_{fluid}^{dissipation}}{(4\, m_{liquid}\, g\, h\, \Phi^{\frac{3}{2}})} = -2^{3/4} \approx \boxed{-1.68}$$

$4\, m_{liquid}\, g\, h\, \Phi^{\frac{3}{2}}$ models that part of total fluid energy (kinetic plus gravitational potential) available to be lost in breaking

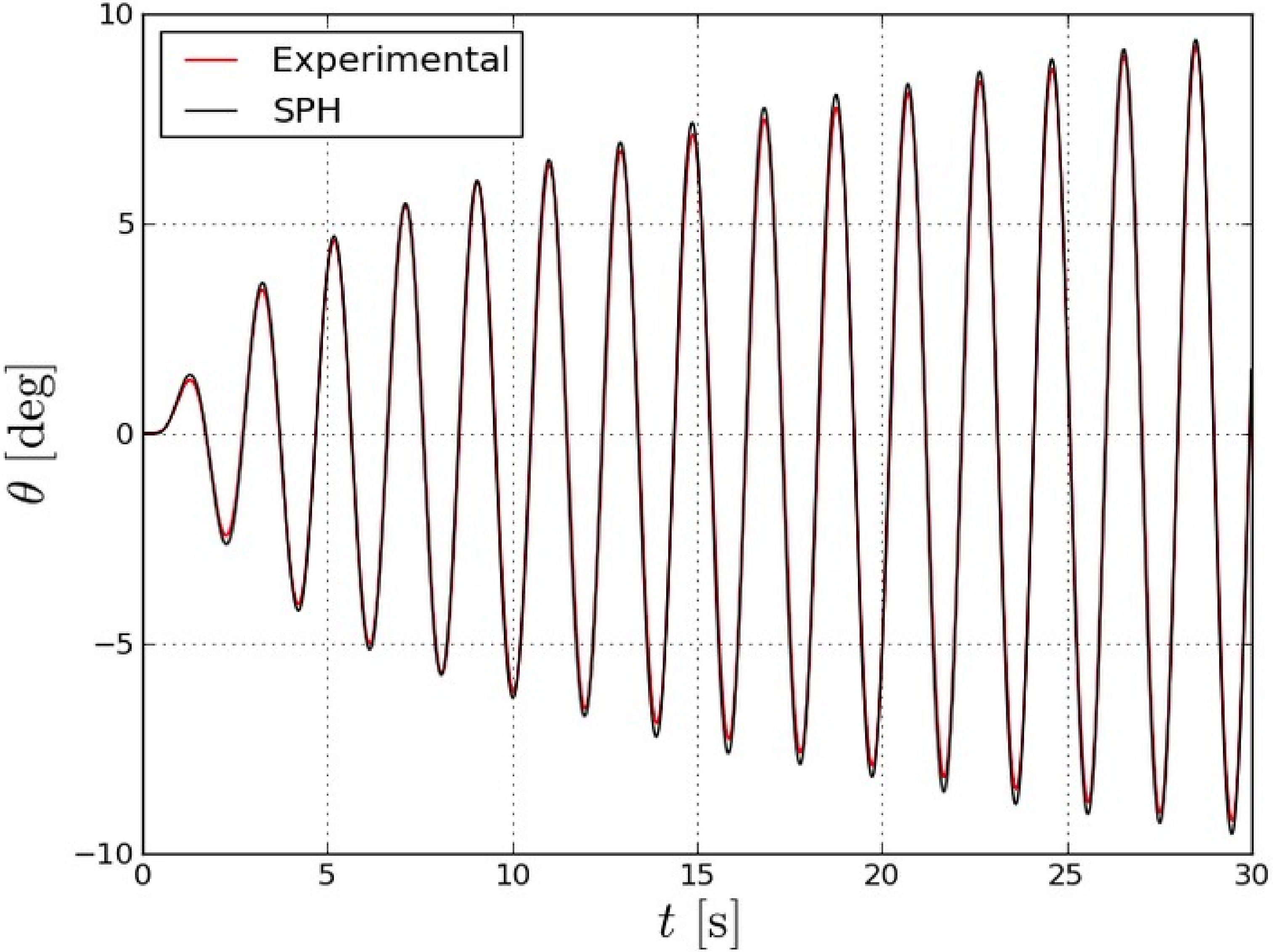
Experiments analysis



this problem can be useful to challenge your solver



this problem can be useful to challenge your solver (Cercos-Pita, 2015, Colagrossi et al., 2011, 2013)



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Final remarks

1. taking dam-break as validation case suggests the need to pay attention to confidence intervals of experimental pressure data.

2. coupling makes sloshing inspiring, challenges free-surface flow solvers by demaning efficient long sims.

Refs.

Lobovský, L., Botia-Vera, E., Castellana, F., Mas-Soler, J., and Souto-Iglesias, A. (2014). Experimental investigation of dynamic pressure loads during dam break. Journal of Fluids and Structures, 48:407-434.

Bulian, G., Souto-Iglesias, A., Delorme, L., and Botia-Vera, E. (2010). SPH simulation of a tuned liquid damper with angular motion. Journal of Hydraulic Research, 48(Extra Issue):28-39.

Bouscasse, B., Colagrossi, A., Souto-Iglesias, A., and Cercos-Pita, J. L. (2014). Mechanical energy dissipation induced by sloshing and wave breaking in a fully coupled angular motion system. Part 1. theoretical formulation and numerical investigation. Physics of Fluids, 26(3).

Bouscasse, B., Colagrossi, A., Souto-Iglesias, A., and Cercos-Pita, J. L. (2014). Mechanical energy dissipation induced by sloshing and wave breaking in a fully coupled angular motion system. Part II. experimental investigation. Physics of Fluids (1994-present), 26(3).

Cercos-Pita, J. L. (2015). Aquagpusph, a new free 3d SPH solver accelerated with opencl. Computer Physics Communications, 192(0):295-312. http://canal.etsin.upm.es/aquagpusph/

Colagrossi, A., Souto-Iglesias, A., Antuono, M., and Marrone, S. (2013). Smoothed-particle-hydrodynamics modeling of dissipation mechanisms in gravity waves. Phys. Rev. E, 87:023302.

Colagrossi, A., Antuono, M., Souto-Iglesias, A., and Le Touzé, D. (2011). Theoretical analysis and numerical verification of the consistency of viscous smoothed-particle-hydrodynamics formulations in simulating free-surface flows. Physical Review E, 84:26705+.

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THE END

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THANK YOU OURENSE SPH GROUP!!!