Dam Break Flow Benchmarks: Quo Vadis?

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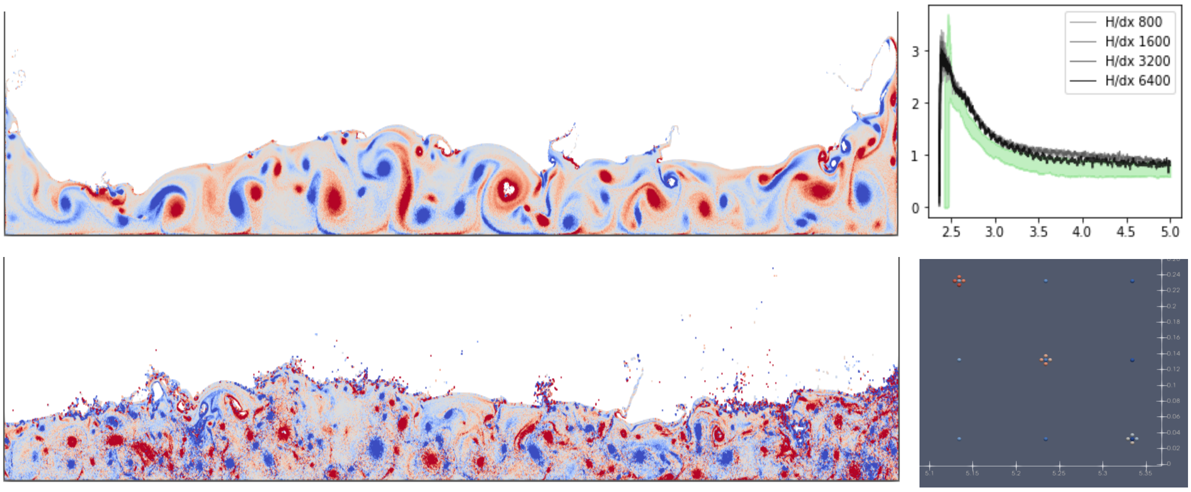
The fluid dynamics community uses dam-break flows as complex benchmarks for rapid and violent fluid-structure interactions. Several variants exist as for the objects which the water first impacts on. In any case, the air phase, surface tension, wall boundary layers and cycles of splashing and sloshing each influence in interlocked stages the free-surface oscillations, breaking and fragmentation; the formation of cavities; the flow velocities; and the pressure loads. A nonstationary, inhomogeneous and anisotropic forcing induces agitation not amenable to conventional frameworks for turbulence.

Impacts on a vertical wall are in focus here after the attention received from experimentalists and modellers. As for experiments, no measurements regard the turbulent stages, while pressure loads regard the early potential-flow stages. The data present flaws in the apparatus (Buchner 2002) or a wide intrinsic variability (Lobovský et al 2014). As for the modelling, Marrone et al 2011 show that reduced 2D cases still require the same piecemeal approach as 3D cases. Nonetheless, 2D dam breaks serve well as a numerical benchmark for different SPH exercises or across CFD methodologies (Park et al 2012), in spite of the phenomenological difference between 2D and 3D turbulence.

Here, we advance fourfold the resolution of the state-of-the-art for a single-phase 2D dam break set by Meringolo et al 2019. An effective Reynolds number of 256,000 reveals vortical features unseen at $Re_{eff} \cong 10^4$, as current in the SPH literature (Figure, left). Compute loads of 82M particles have been processed with DualSPHysics 5.0 thanks to its GPU acceleration strategy (Dominguez et al 2013). An SPH viscous operator consistent with the Laplacian generates flow structures by scaling the physics appropriately. The simulated flow fields at H/dx=800, 1600, 3200, 6400 are deposited in a public repository (Lipari and Vuik 2021); its items have been downloaded 3300+ times since. Besides, the time series at numerical probes show that increasing the spatial resolution promotes the peak pressure convergence (Figure, right). Arrays of numerical probes, also shown, have been placed in the bulk to record velocity signals and gain insights into the simulation during the turbulent stages.

While compute capabilities afford us simulations with ever more SPH particles, dam-break investigations into ever smaller eddy scales remain feasible only in 2D. Setups complementary to such a line of investigation include two-phase flows and 3D flows at lower resolutions. While the tools in Lagrangian turbulence might offer opportunities to obtain insights from SPH findings, we surely advocate more experiments in all dam-break stages to validate or complement simulations.



Left panels Simultaneous vorticity fields during the sloshing stage at Re_{eff}=32,000 (H/dx=800, top) and 256,000 (H/dx=6400, bottom). **Right panels** Dimensionless time/pressure signals against the experimental variability in Lobovský et al 2014 (top). Numerical probes for velocity signals (below).

References Buchner 2002, PhD Thesis, TU Delft - Dominguez et al 2013: 10.1016/j.cpc.2012.10.015 - Lipari and Vuik 2021: 10.4121/c.5353691 - Lobovský et al 2014:10.1016/j.jfluidstructs.2014.03.009 - Marrone et al 2011 10.1016/j.cma.2010.12.016 - Meringolo et al 2019:10.1016/j.compfluid.2018.11.012 - Park et al 2012: 10.1016/j.oceaneng.2012.01.005