

ERCOFTAC



*SPH European Research Interest Community  
SIG*

*Test-case 2*

## **3D dambreaking**

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*by*

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## 1 Introduction

In the framework of the SPHERIC ERCOFTAC Special Interest Group, several SPH benchmark test-cases are defined by the different participants. This short document describes the second considered test-case, the 3D dambreaking problem developed by Kleefsman et al presented in [1].

## 2 Kleefsman's dambreaking test-case

This part is extracted from [1].

### 2.1 Kleefsman's dambreaking experiment

At the MAritime Research Institute Netherlands (MARIN), experiments have been performed for breaking dam flows. These experiments can be seen as a simple model of green water flow on the deck of a ship. The dambreak is a very popular validation case, because the set-up is easy: no special in- or outflow conditions are needed. In [1], a large tank of  $3.22 \times 1 \times 1$  m is used with an open roof. The right part of the tank is first closed by a door. Behind the door, 0.55 m of water is waiting to flow into the tank when the door is opened. This is done by releasing a weight, which almost instantaneously pulls the door up. In the tank, a box has been placed that represents a scale model of a container on the deck of a ship. During the experiment, measurements have been performed on water heights, pressures and forces. As shown in figure 1, four vertical height probes have been used: one in the reservoir and the other three in the tank. The box was also covered by eight pressure sensors, four on the front of the box and four on the top.

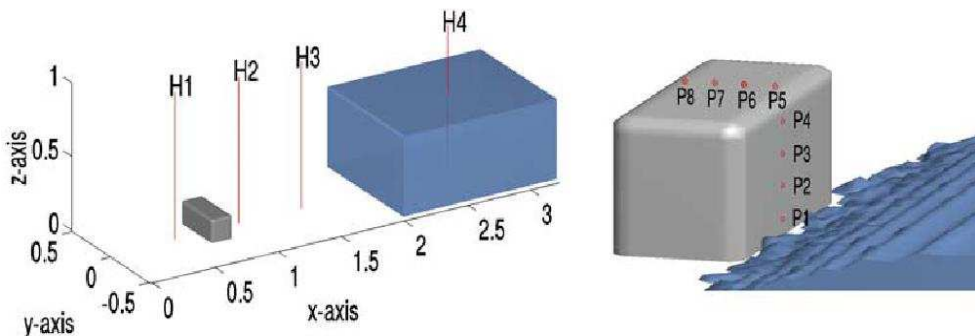


Figure 1: Measurement positions for water heights and pressures in the dambreak experiment.

### 2.2 Kleefsman's dambreaking VOF simulation

The previous dambreaking test-case has been simulated by Kleefsman [1], with a Volume-Of-Fluid method. A fine grid of  $236 \times 76 \times 68$  grid cells has been used with some stretching towards the bottom of the tank. As initial condition of the simulation, the water in the right part of the domain is at rest. When the simulation is started, due to gravity, the water starts to flow into the empty part of the tank. The simulation is continued for 6 s with an automatically adapted time step using maximum CFL-numbers around 0.75, resulting in a time step of the order  $0.001$  s. The comparisons shown on figures 2 and 3, reveal an excellent qualitative agreement between experimental and numerical results. Quantitative comparisons, including

- Vertical water height history at probes  $H_4$  and  $H_2$  (see figure 4)
- Pressure time histories at pressure sensors  $P_1$ ,  $P_3$ ,  $P_5$  and  $P_7$  (see figure 5)

also show a very good behaviour of the numerical method.

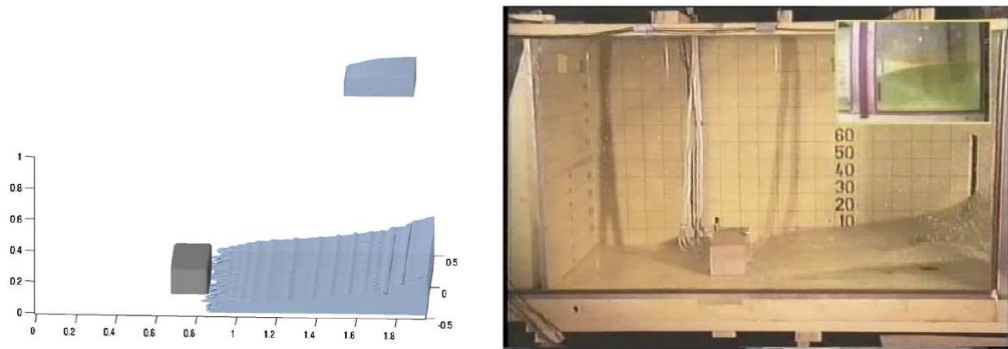


Figure 2: Snapshot of a dambreak simulation with a box in the flow compared with experiment at time 0.4 s [1].

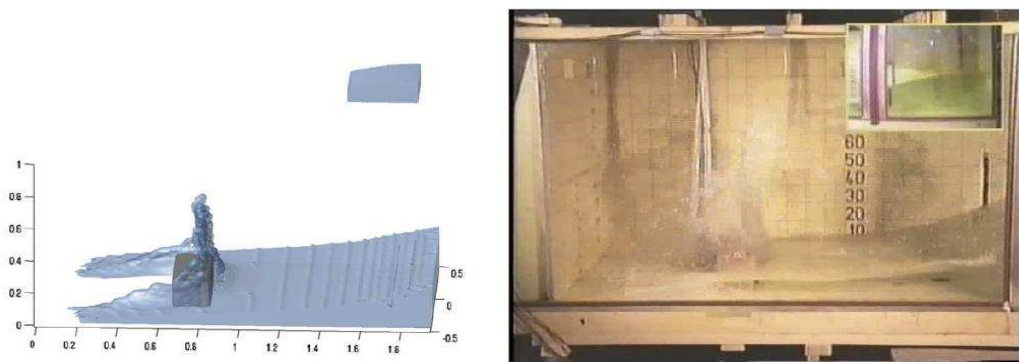


Figure 3: Snapshot of a dambreak simulation with a box in the flow compared with experiment at time 0.56 s [1].

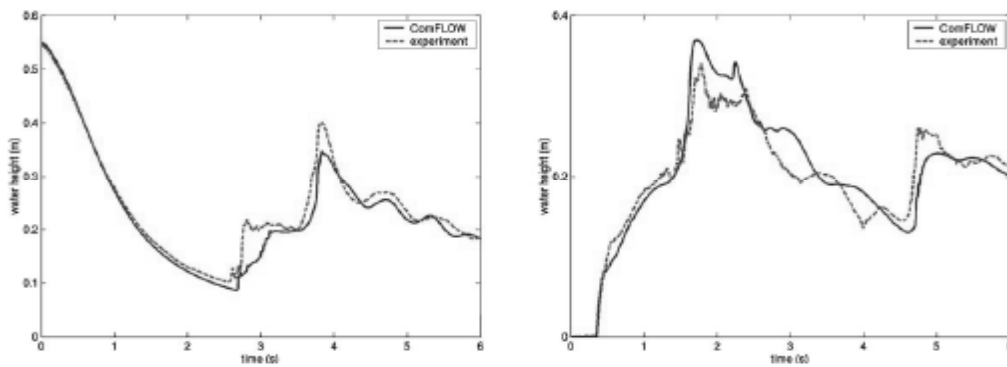
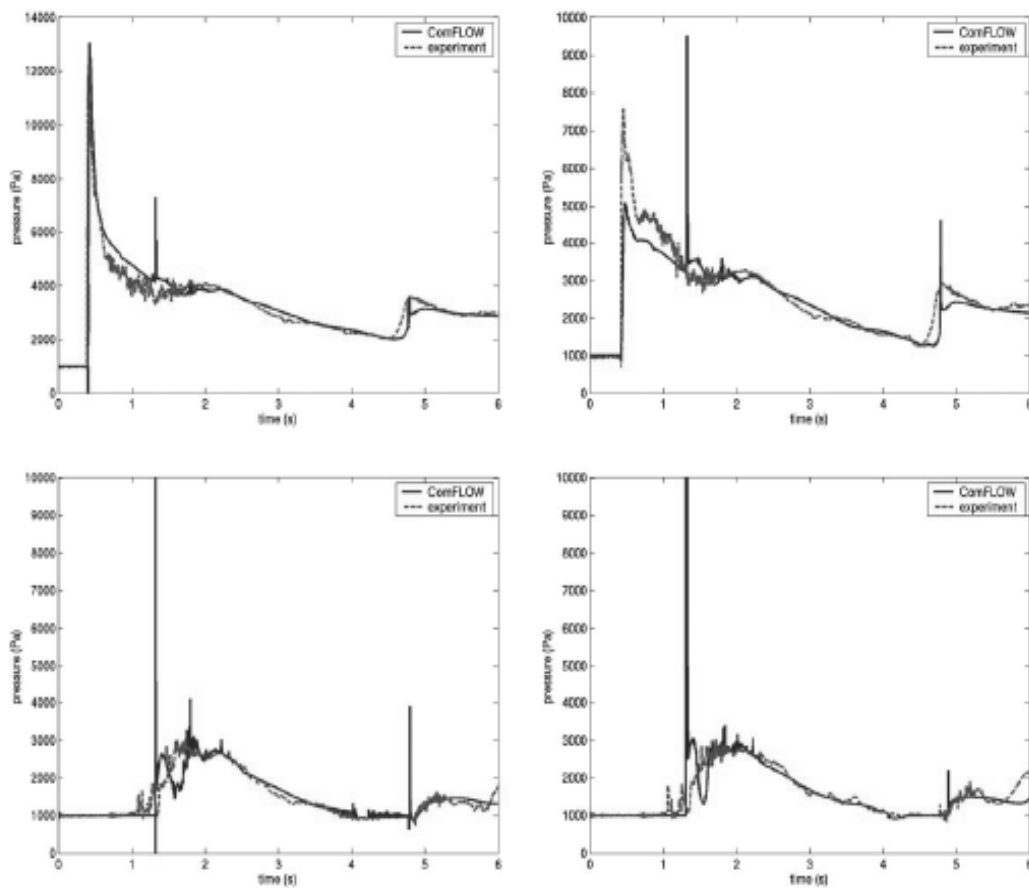


Figure 4: Vertical water heights in the reservoir  $H_4$  (left) and the tank  $H_2$  (right) [1].

Figure 5: Pressure time histories at  $P_1$ ,  $P_3$ ,  $P_5$  and  $P_7$  [1].

### 3 Kleefsman's dambreaking simulation by SPH

The previous Kleefsman's dambreaking test-case is here designed for the SPH method.

#### 3.1 System geometry

The geometry of the system is described on figure 6 while the description of the box is presented on figure 7.  $H_i$  correspond to the vertical wave probes while  $P_i$  are the pressure sensors used in the experiment. In both figures, all dimensions are in meters.

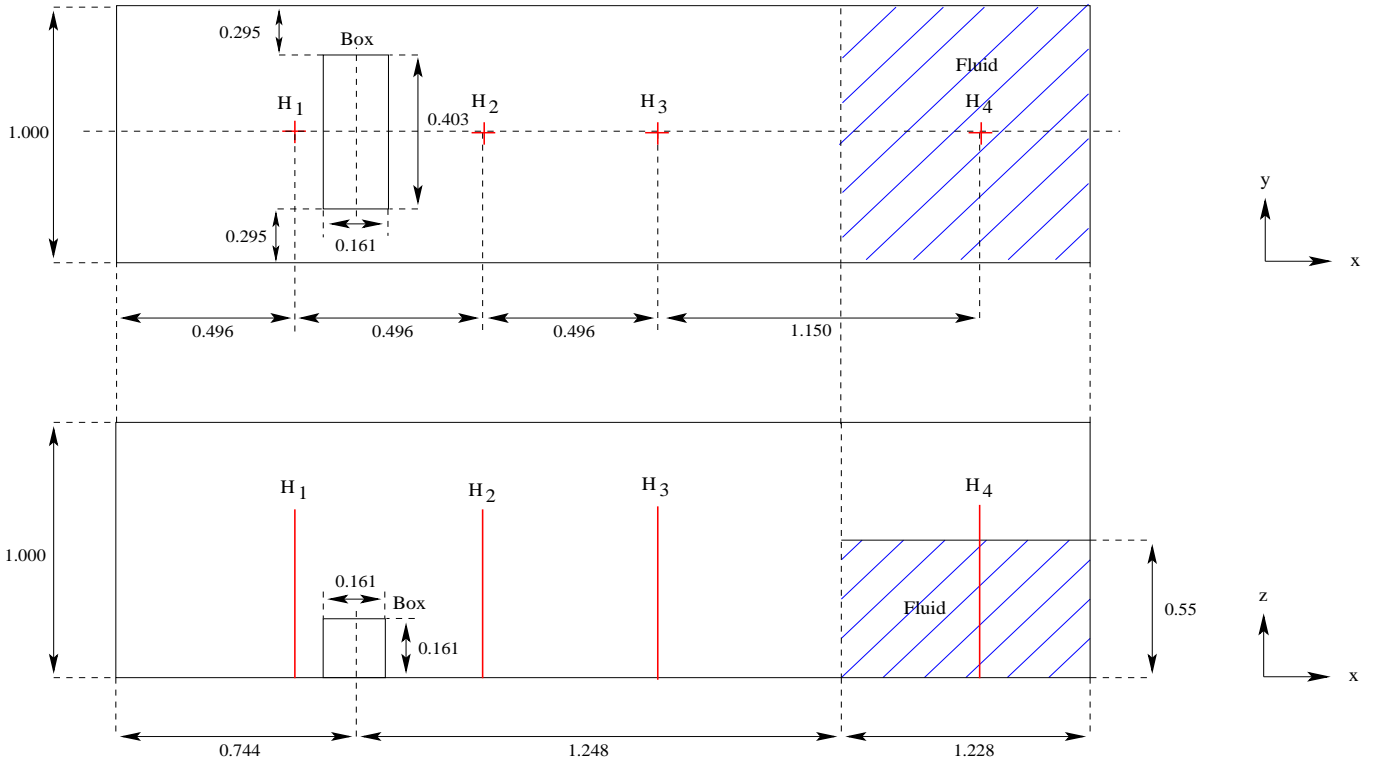


Figure 6: General description of the system : top (top picture) and side (bottom picture) views.

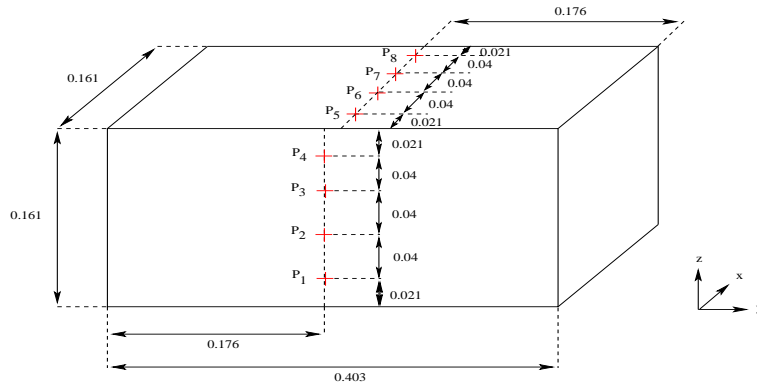


Figure 7: Description of the box.

Fluid particles $(x, y, z)$	$67 \times 54 \times 30$
Bottom wall particles $(x, y)$	$183 \times 62$
Side wall particles $(x, z)$	$183 \times 55$
Side wall particles $(y, z)$	$54 \times 55$
Particle initial spacing: $\delta r$ (cm)	$55/30$

Table 1: System discretization (fluid and walls) for the dambreaking simulation.

Top wall particles $(x, y)$	$8 \times 21$
Side wall particles $(x, z)$	$10 \times 9$
Side wall particles $(y, z)$	$21 \times 9$

Table 2: Box discretisation for the dambreaking simulation.

### 3.2 System discretization

In order to consider a "reasonable" number of particles, 30 fluid particles are distributed along the vertical direction. Thus, the initial interparticle distance is equal to  $55/30$  cm. Walls are discretized with wall particles and three layers of fictitious particles (for codes using this kind of boundary treatment), as described in table 1. The box is also discretized with wall particles and filled with fictitious particles, as presented in table 2. The different numbers of particles used for this test case are presented in table 3. Examples of the discretized system are presented in figure 8 (in order to facilitate visualization, some wall and fictitious particles were removed on this figure). A side and top views of the particle system are also shown on figures 9 and 10.

### 3.3 Fortran geometry file

The previous discretization has been established with the fortran file `test_case_2.f`, which can be described according to

1. Interparticle distance definition (lines 64 to 66)
2. Distribution of fluid particle (lines 67 to 85).
3. Distribution of wall particles relative to the system (lines 86 to 150).
4. Distribution of wall particles relative to the box (lines 151 to 212).
5. Distribution of fictitious particles relative to the system (lines 213 to 286).
6. Distribution of fictitious particles relative to the box (lines 286 to 304).
7. Checking for particle non-coincidence (lines 313 to 332)
8. Boundary search (lines 334 to 359).
9. Initializing file writing (lines 361 to 378).

Fluid particles (NPARF)	108 540
Wall particles (NPARB)	38 142
Fictitious particles	113 592
Total (NPART)	260 274

Table 3: General particle discretization.

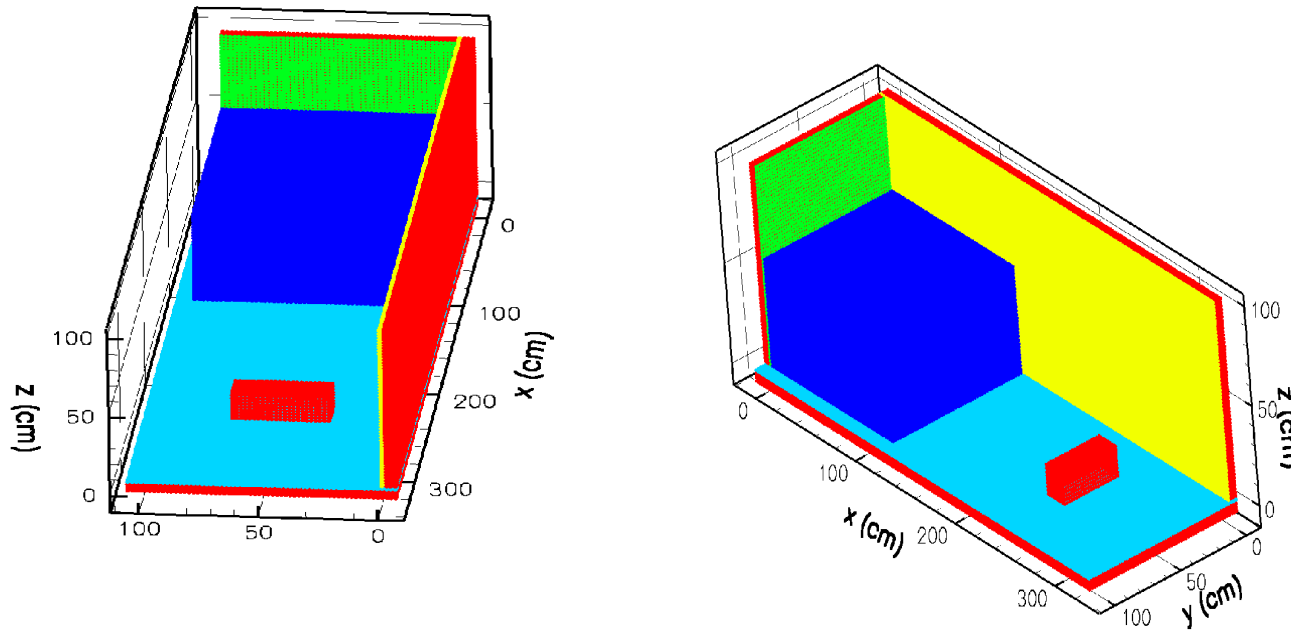
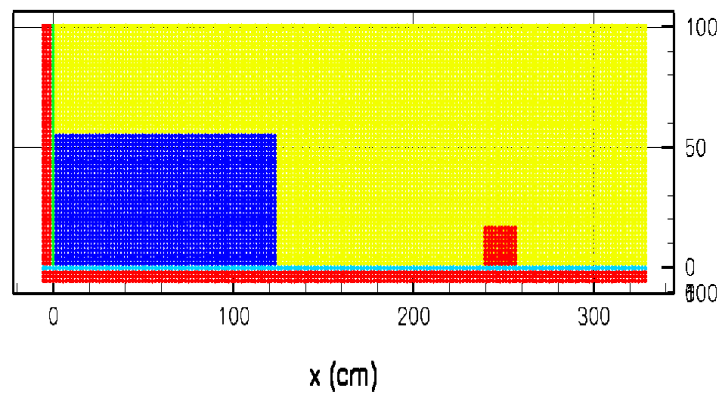
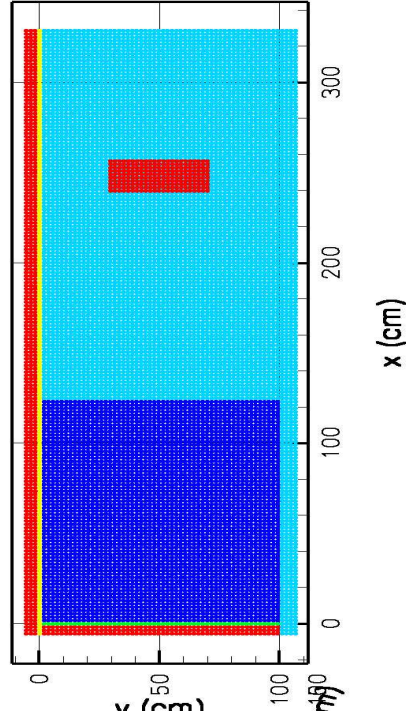


Figure 8: 3D views of the SPH system.

Figure 9: Side view ( $x, z$ ) of the SPH system.

Figure 10: Top view  $(x, y)$  of the SPH system.

Density ( $kg.m^{-3}$ )	1000.
Kinematic viscosity ( $m^2.s^{-1}$ )	$1.10^{-6}$

Table 4: Physical properties of water.

### 3.4 Simulation parameters and validation

#### 3.4.1 Physical and numerical parameters

The fluid used for this test-case is water, for which the main physical properties are presented in table 4. As the VOF Kleefsman's simulation, the SPH one has to last 6 seconds.

#### 3.4.2 Qualitative results

In order to test the ability of each SPH code to reproduce such flows, a movie of the experiment (`test_case_2_exp_movie.mpg`) is furnished. All users are then be able to qualitatively compare the shape of the free surface and the fluid velocity to the experiment.

#### 3.4.3 Quantitative results

For this benchmarks, the quantitative outputs of interest are:

- Vertical water height history at probes  $H_1$  to  $H_4$
- Pressure time histories at pressure sensors  $P_1$  to  $P_8$

The file `test_case_2.xls` contains all the experimental data. In order to compare the different SPH codes, the users are asked to write their numerical data according to the same format.



## References

- [1] K. M. T. Kleefsman, G. Fekken, A. E. P. Veldman, B. Iwanowski, and B. Buchner. A volume-of-fluid based simulation method for wave impact problems. *J. Comp. Phys.*, 206:363–393, 2005.