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DAM BREAK FLOW SIMULATION ON GRID

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Abstract. In this contribution we report on a dam break flow simulation on gLite based grid infrastructure. The dam break problem including breaking waves is solved by the pseudo-concentration method improved by interface sharpening technique. The developed interface sharpening procedure helps to preserve interface sharpness and mass conservation. The computed position of the leading edge of water column has been compared with the experimental measurements.

1. Introduction

Dam break flow has been the subject of extensive research for a long time [1]. The original problem has direct application in the industrial areas of fluid mechanics and environment protection. The breaking wave phenomena occurring in some cases of a dam break problem includes it into the class of complex applications such as solitary wave propagation, tank sloshing and water on a ship deck simulation. Some experimental measurements were performed on the dam break flow or collapse of a liquid column problem [1-2]. Photographs showing the time evolution of the collapsing column as well as the wave returning after hitting a wall on the opposite side are available for the purpose of evaluating the numerical methodology on the basis of flow visualization. Measurements of the exact interface shape are not available, but some secondary data such as the reduction of the water column height [2] can be employed for quantitative comparison of the obtained results. Several modifications of the broken dam problem have been extensively used as classical test cases for numerical simulation of free surfaces and moving interfaces [3-4]. However, the universal, accurate and efficient numerical technique for breaking wave simulation attracts close attention of research community and software developers.

Over the past 30 years, researchers have put a lot of effort into developing various numerical methods to simulate the moving interface flows governed by the Navier-Stokes equations. All numerical methods for modelling of the moving interface flows are based on interface tracking approach or interface capturing approach. In former, the liquid region is subdivided by a mesh, while each cell is deformed according to the movement of the interface and computed velocities [5-6]. However, this approach requires remeshing procedures to avoid of computation failure due to serious distortion of cells or elements. These methods are unable to cope naturally with interface interacting with itself by folding or rupturing. In the interface capturing approach, the mesh remains fixed and moving interface can not be directly defined by the mesh nodes. Therefore, additional technique is necessary to define the areas occupied by fluid or gas on either side of the interface. The marker-and-cell method [3], the volume of fluid method [4] and the level set method [7] are well known methods using the interface cap-

experiments have shown that the extreme sharpening is necessary only at the beginning of the time interval $t = [0; 0.09]$ s. Thus, the accuracy of the obtained results is strongly influenced by the numerical parameters, but it is almost independent of the resolution of the finite element mesh, if sufficiently dense FE meshes are used.

Interface sharpness and mass conservation. The quantitative comparison of the numerical results and the experimental measurements has shown that the detailed analysis of the interface sharpening parameters should be performed in order to develop an accurate and efficient interface sharpening procedure. The sharpening frequency ns determines how often the interface sharpening procedure should be applied. Usually, interface sharpening has been performed at regular time intervals (each k time step). Fig. 4a shows time evolution of the total number of nodes *totnum*, belonging to the interface ($0 < \varphi < 1$). The value of parameter a is fixed and equals to 1.5. The curve nsk0 illustrates how the interface grows without sharpening. It is obvious that this process is drastically influenced by the numerical diffusion. On the contrary, the interface sharpening performed at each time step reduces the interface thickness to one finite element (the curve nsk1). However, in this case, the moving interface can lose its smoothness. The results obtained in sharpening the interface less frequently are quite acceptable. The curve nsk10 visualizes the case $ns = 10$.

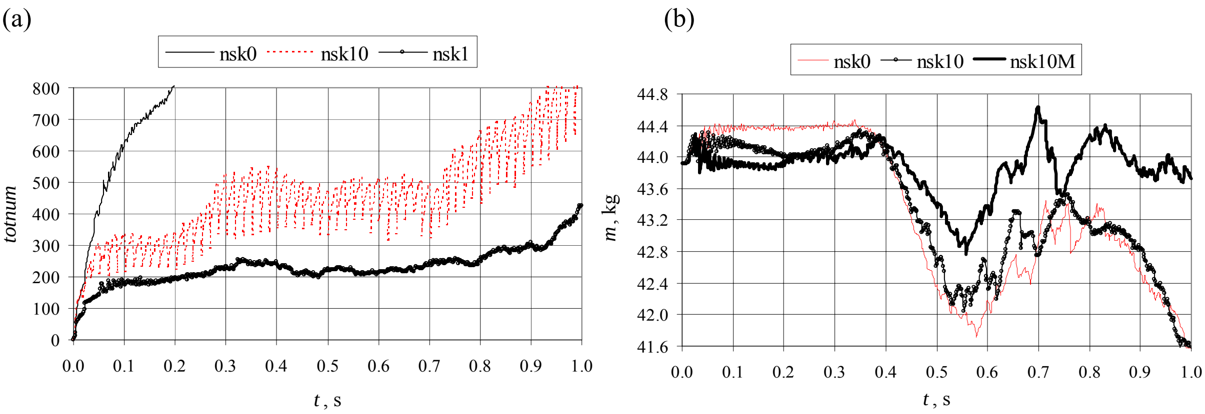

Fig. 4. Interface sharpness (a) and mass conservation (b).

Mass conservation is one of the most important tasks for any interface sharpening procedure. Fig. 4b shows mass evolution in time for several interface sharpening cases. The time interval $t = [0.4; 0.7]$ s illustrates the case when water is leaving the computational domain and is coming back. In order to preserve the consistency between the flow physics and the numerical techniques, mass correction is automatically switched off in this special case. All plotted curves are actually of the same character, but quantitative results are quite different. The significant mass loss is observed when interface sharpening is not applied (the curve nsk0). The interface sharpening without mass correction at regular time intervals (the curve nsk10, $ns = 10$) does not significantly reduce the mass loss. The application of mass correction to regular interface sharpening (the curve nsk10M, $ns = 10$) significantly improves mass conservation.

6. Conclusions

In this paper, the dam break problem has been solved by the pseudo-concentration method and the developed interface sharpening technique. Dam break flow simulation has been efficiently performed on gLite based BalticGrid infrastructure. The numerical approach has been validated by quantitative comparison with the experimental measurements. The computed position of the leading edge of the collapsing water column has been in good agreement with the experimental data. The regular interface sharpening with mass correction is able to preserve interface sharpness and mass conservation. The accurate numerical solution of the dam break problem, including highly non-linear breaking waves, proves that the developed numerical technique is capable of simulating moving interfaces undergoing large topological changes.

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References
[1] J.C. Martin, W.J. Moyce // *Philos. Trans. Roy. Soc. London*, **A244** (1952) 312.
[2] S. Koshizuka, H. Tamako, Y. Oka // *J. Comput. Fluid Dynamics* **4** (1995) 29.
[3] F.H. Harlow, J.E. Welch // *J. Phys. Fluids*, **8** (1965) 2182.
[4] C.W. Hirt, B.D. Nichols // *J. Comput. Physics* **39** (1981) 201.
[5] A. Masud, T.J.R. Hughes // *Comput. Methods Appl. Mech. Eng.* **146** (1997) 91.
[6] F. Del Pin, E. Oñate, R. Aubry // *Computers & Fluids* **36** (2007) 27.
[7] S. Osher, J.A. Sethian // *J. Comput. Physics* **79** (1988) 12.
[8] R. Löhner, C. Yang, E. Oñate // *Comput. Methods Appl. Mech. Eng.* **195** (2006) 5597.
[9] E. Thompson // *Int. J. Numer. Methods Fluids* **7** (1986) 749.
[10] R.W. Lewis, K. Ravindran // *Int. J. Methods Eng*. **47** (2000) 29.
[11] T.E. Tezduyar // *Computers & Fluids*, **36** (2007) 207.
[12] D.A. Di Pietro, S. Lo Forte and N. Parolini // *Appl. Numer. Math*. **56** (2006) 1179.
[13] A. Kačeniauskas and P. Rutschmann // *Int. J. Informatica*, **15** (2004) 363.
[14] A. Kačeniauskas // Mechanika, **69** (2008) 35.
[15] int.eu.grid: http://www.interactive-grid.eu/
[16] GlassFish: https://glassfish.dev.java.net/
[17] HDF5: http://hdf.ncsa.uiuc.edu/products/hdf5/
[18] *VTK User's Guide Version 5*, Inc. Kitware. 5th Edition, 2006.
[19] GVid: http://www.gup.jku.at/gvid/