11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

NUMERICAL STUDY OF WALL FRICTION EFFECTS ON DAM-BREAK FLOWS IN THE PRESENCE OF AN OBSTACLE

Alexander I. Khrabry[1*], Evgueni M. Smirnov[1], Dmitry K. Zaytsev[1]

[1] St.-Petersburg State Polytechnic University
Polytechnicheskaya str. 29, St.Petersburg, 195251, Russia
aero@phmf.spbstu.ru

Key Words: *Free surface flows, Dam-break flow, VOF method, Wall friction*

In case of high Reynolds number, computations of free surface flow developing over a wall are performed usually with application of the standard wall function technique or even with the slip condition. It is well known however that the standard wall functions do not perform well in case of high values of adverse pressure gradient. Such a problem arises in particular when the dam-break flow interacts with an obstacle, and due to this interaction a local separation zone can occur. The present contribution covers results of numerical simulation of dam-break flows using computational grids with varied degree of refinement to the wall, up to the case of low-Re grids providing complete resolution of the viscous sublayer. The computations, based on application of the Volume-of-Fluid (VOF) method and the M-CICSAM scheme [1] for the interface resolution, are performed with an in-house unstructured-grid finite-volume Navier-Stokes code of second order accuracy. To introduce the eddy viscosity effects, the Menter SST turbulence model [2] is used. For computational grids characterized by $Y^+>30$ the standard wall functions are used, and the low-Re model wall conditions are applied in case of $Y^+ = O(1)$.

Figure 1 presents some results obtained for the 2D flow developing after break of a dam model and interacting with a vertical wall. The computations have been performed under experimental conditions reported in [3]. At the initial time instant, water occupies a volume of 0.2x0.4 m, as shown in the upper-left corner of Figure 1a. The dam break is modeled via removing the partition wall according to its vertical-shift time dependence defined in [3]. For some time interval, water is displacing the air initially adjacent to the bottom wall. Note here that in the case of low-Re grids, one can face a problem of formation of a very thin air layer that is not displaced properly due to very low velocity in the viscous sublayer. As a result, wall friction is not predicted correctly. In the present work, this difficulty has been overcome after introducing an artificial diffusivity into the transport equation of the VOF-function that acts just near the wall. By t=0.52s, as seen in Figure 1a, the water stream has already interacted with the right vertical wall. Taking the wall friction into account leads to formation of a separation zone in the corner region, and this process is sensitive mostly to the grid resolution near the bottom wall. The presence of this separation zone affects the water-air interface considerably. By a later time instant, t=0.99 s, distinctions between the computational cases under comparison become more pronounced (Figure 1b). At that, results for the low-Re grid with maximum Y^+ values of about unity are in the best agreement with the experimental observations [3].

The second case considered is interaction of the water stream with a triangular obstacle (Figure 2). The present 2D computations have been carried out for the test configuration given in [4]. For this case, results obtained with a low-Re grid (with typical $Y^+<1$) are close to those for a high-Re grid ($Y^+>30$), but differ dramatically from the case of slip wall conditions. Action of the bottom wall friction leads to formation of two separation "bubbles" and two corresponding hills at the free surface, seen in the experimental photo as well.

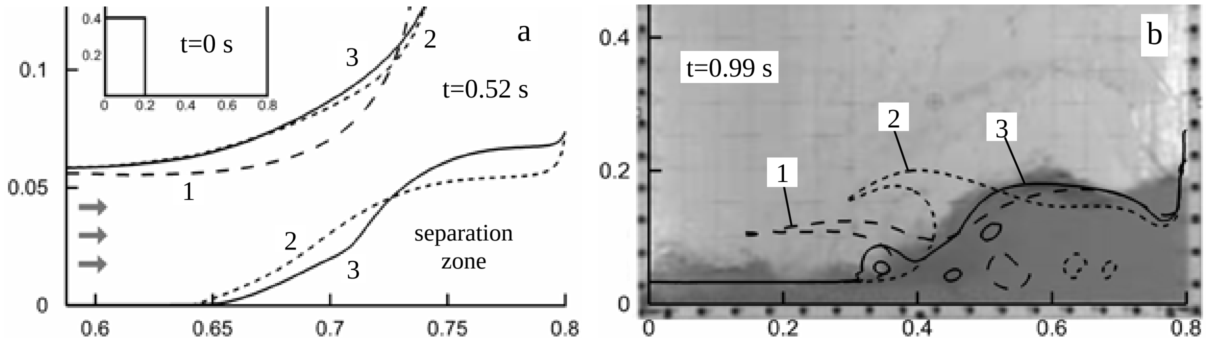

Figure 1: Simulation results for the test case of Hu & Sueyoshi [3]: (a) water-air interface and separating streamline computed for the time instant of 0.52s and (b) water-air interface in combination with an experimental photo for the time instant of 0.99s: computations with (1) slip wall condition, (2,3) with no-slip condition at (2) $Y^+=80$ and (3) $Y^+=1$

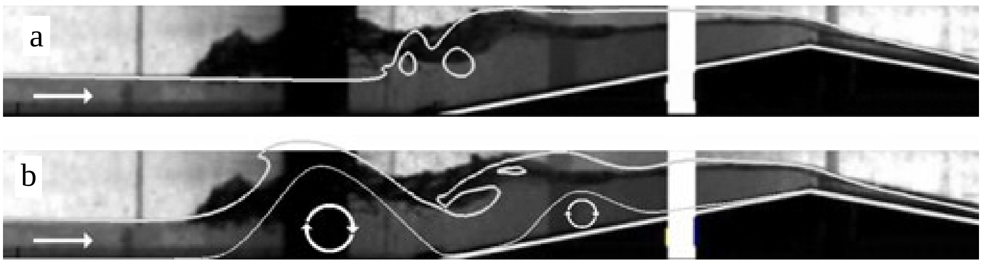

Figure 2: Simulation results for the test case of Soares-Frazao [4] in combination with experimental photo: (a) an instant form of free surface computed with slip wall condition, (b) free surface and separation bubbles computed for same time instant with no-slip condition using a grid with $Y^+=1$

Acknowledgements The work was partially supported by the Russian Foundation of Basic Research (grant 14-07-00065).

REFERENCES

[1] T. Waclawczyk and T. Koronowicz, Remarks on prediction of wave drag using VOF method with interface capturing approach. *Archives of Civil and Mechanical Engineering*, Vol. **8**, No.1, pp. 5-14, 2008.

[2] F. R. Menter, Two equation eddy-viscosity turbulence models for engineering applications. *AIAA Journal*, Vol. **32**. pp. 1598-1605, 1994.

[3] C. Hu and M. Sueyoshi, Numerical simulation and experiment on dam break problem. *Journal of Marine Science and Application*, Vol. **9**, issue 2, pp. 109 – 114, 2010.

[4] S. Soares-Frazao, Experiments of dam-break wave over a triangular bottom sill. *Journal of Hydraulic Research*, Vol. **45**, Extra Issue, pp. 19 – 26, 2007.