ID50- COMPARING MESH-FREE AND MESH-BASED NUMERICAL METHODS TO DEAL WITH SLOSHING TANK PROBLEMS

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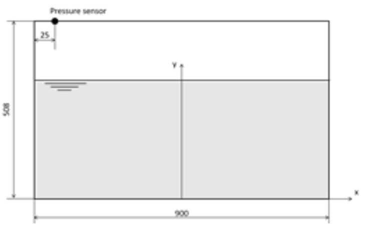
Sloshing is a highly nonlinear movement that can lead to dynamic loads on tanks. These loads can affect, for example, Liquefied Natural Gas (LNG) vessels by modifying the movement of ships on waves. This is a key point in the design of anti-roll tanks used to damp the roll movement of ships. The coupling effect between sloshing and motions of ship can be analysed by means analytical, experimental and numerical methods. Analytical and experimental methods have some drawbacks as, for example, the simplification hypothesis of the analytical methods make that only simplified models can be analysed and the experimental methodologies need from expensive experimental facilities that limit the number of cases. Numerical methods are a good option to overcome these drawbacks. The numerical methods can use two different methodologies: mesh-free and mesh-based methods. The mesh-based methods discretise the domain of study using fine meshes to study, for example, the propagation of waves. These methods usually require expensive mesh generation and have severe technical challenges associated with the implementation of conservative multi-phase schemes. Free surface elevation is obtained by using volume of fluid methods (VOF). The mesh-free methods discretise the fluid domain using particles. Then, these methods analyse the flow by following the fluid particles. The mesh-free methods allow overcoming part of the drawbacks that characterise the mesh-based schemes, despite their usually bigger computational cost. Methods such as Smoothed Particle Hydrodynamics (SPH) and the particle finite element method (PFEM) are examples of mesh-free schemes. In SPH no special tracking is used to detect the free surface and the domain is multiply-connected due to the Lagrangian nature the method. Consequently, large deformations of free surface can be efficiently treated since there is no mesh distortion, making SPH an ideal technique to study highly non-linear phenomena. González-Cao et al. show in [1] a comparison of this two methodologies applied to fluid-structure interaction (FSI) problems. The authors compare the results of the propagation of regular waves and their impacts on a static vertical wall of a structure with a cantilever slab using the mesh-free method DualSPHysics [2] and the mesh-based method IHFOAM [3]. In this work the authors aim to extend the previous comparison studies focused on the interaction of fluid with static structures to moving bodies by comparing the results obtained in physical tests (reference data) of a sloshing tank with the numerical results obtained using DualSPHysics and OpenFOAM. The analysed case is a SPHERIC Benchmark Test Case 10 (https:// spheric- sph. org/ tests/ test- 10), consisting of a sloshing tank of 900 mm × 508 mm with an initial water level equal to 355.3 mm. Figure 1 shows a scheme of the experimental set-up. Reference data (experimental) of the time series of pressure of the impacts in the roof of the tank (see Figure 1) was obtained from [4-7]. The time series of pressure obtained with DualSPHysics, OpenFOAM along with the experimental data are depicted in Figure 2. The numerical results are quite similar to the reference solution.

This work shows that mesh-free methods have achieved the required level of maturity to reproduce sloshing problems, attaining a level of accuracy and efficiency similar to mesh-based methods.



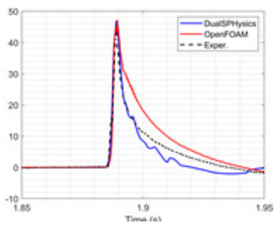


Fig. 1. Scheme of the experimental setup.

Fig. 2. Time series of pressure obtained with DualSPHyics (blue line), OpenFOAM (red line) and in the experimental tests (black dashed line).

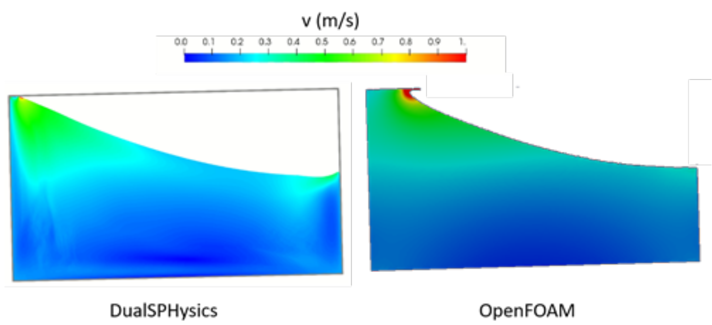


Fig. 3. Snapshot of the numerical simulations of the sloshing tank carried out with DualSPHysics and OpenFOAM.

REFERENCES

[1] J. González-Cao, C. Altomare, A.J.C. Crespo, J.M. Domínguez, M. Gómez-Gesteira and D. Kisacik, "On the accuracy of DualSPHysics to assess violent collisions with coastal structures", Computer and Fluids, vol. 179, pp. 604-612, 2019.

[2] J.M. Domínguez, G. Fourtakas, C. Altomare, R.B. Canelas, A. Tafuni, O. García-Feal, I. Martínez-Estévez, A. Mokos, R. Vacondio, A.J.C. Crespo, B.D. Rogers, P.K. Stansby, M. Gómez-Gesteira. "DualSPHysics: from fluid dynamics to multiphysics problems". Computational Particle Mechanics, 2021. DOI:10.1007/s40571-021-00404-2. *[3] P. Higuera, J.L. Lara, I.J. Losada, "Three-dimensional interaction of waves and porous coastal structures using OpenFOAM®. Part I: Formulation and validation", Coastal Engineering, vol. 83, pp. 243-258, 2014.*

[4] L. Delorme, A. Colagrossi, A. Souto-Iglesias, R. Zamora-Rodríguez, and E. Botia-Vera, "A set of canonical problems in sloshing. Part I: Pressure field in forced roll. Comparison between experimental results and SPH," Ocean Engineering, vol. 36, no. 2, pp. 168–178, February 2009.

[5] A. Souto-Iglesias, E. Botia-Vera, A. Martin, and F. Pérez-Arribas, "A set of canonical problems in Sloshing. Part 0: Experimental setup and data processing," Ocean Engineering, vol. 38, 16, pp. 1823-1830, 2011. DOI.: https://doi.org/10.1016/j.oceaneng.2011.09.008.

[6] A. Souto-Iglesias, E. Botia-Vera, G. Bulian (2011, June). Repeatability and Two-Dimensionality of model scale sloshing impacts. In International Offshore and Polar Engineering Conference (ISOPE). The International Society of Offshore and Polar Engineers (ISOPE).

[7] E. Botia-Vera, A. Souto-Iglesias, G. Bulian, L. Lobovský (2010). Three SPH Novel Benchmark Test Cases for free surface flows. In 5th ERCOFTAC SPHERIC workshop on SPH applications.