UNIVERSITÀ DEGLI STUDI DI SALERNO

C.U.G.RI.
Consorzio inter-Universitario
per la Previsione e Prevenzione dei Grandi RIschi
Università di Salerno - Università di Napoli "Federico II"

Department of Civil Engineering, September 12, 2014, h. 12.00, Room 126

SEMINAR NOTICE

Coupled SPH /FEM simulations for free-surface flows and fluid-structure interaction

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Smoothed Particle Hydrodynamics (SPH) is a method for solving continuum dynamics and has been demonstrated to be a suitable method for simulation of fluid flow, in particular when free surfaces are involved. Since SPH allows straightforward handling of rapidly changing surface geometry and topology, it is an attractive method to simulate various free-surface flow phenomena such as slamming phenomena, water entry of dropped objects and interaction of floating structures, e.g. ships, with severe waves. To describe the displacements and deformation of any structural components involved, the finite element (FE) method is the most appropriate solution tool. Hence the mixed FE-SPH approach available within the commercial explicit dynamics numerical code VPS provides a numerical solution methodology for fluid-structure interaction (FSI) relevant for many maritime and hydraulic engineering studies.

Within the VPS software package from ESI-Group, interaction between fluids represented by SPH and moving or deformable structures represented by finite elements can be modelled by one of the available sliding interface algorithms. The employed sliding interface is based on the penalty formulation similar to the contact algorithm standardly used in structural dynamics. This type of contact has been validated by the vertical motion of floating bodies (Groenenboom and Cartwright, 2010).

The applicability of the coupled SPH/FE approach to FSI simulations is demonstrated in a test case proposed by Antoci et al. (2007), who provided experimental as well as numerical data for the case of a reservoir from which the water escapes through an opening created by the deformation of an elastic gate. For the initial VPS simulations it was found that the agreement of the VPS results with the experimental data was less good than for independent simulations in which SPH was also used for the elastic gate. Further investigation revealed that the pure SPH simulations had employed a linear elastic material model for the gate with an elastic modulus at small strains which is not representative for the strains reached during the outflow. When the experimental stress-strain curve was used for the FE model of the gate material, the VPS results were found to be in good agreement with the experimental data (Lobovský and Groenenboom, 2009).

Selected engineering studies involving fluid-structure interaction will be discussed. One such test case is the impact of a tsunami type of wave on a typical structure, namely a tank for liquid natural gas (LNG), as depicted in figure 1. In this case, in addition to wave slamming and subsequent flooding, some debris (automobiles) was placed in front of the structure to illustrate the capacity of the model to generate projectiles, and the tank was modeled as deformable. The simulation depicted in figure 1 was performed for rigid structures. When elastoplasticity was allowed, a complex collapse path was observed, starting by the inward buckling of the dome. However in terms of simulation resource requirements, the rigid case and the elastoplastic case are very different. For the same basic model, the CPU time is one to two orders of magnitude more for the case of a collapsible model as compared to a rigid model. This is because the algorithmic stability of the elastoplastic material necessitates a time step size significantly smaller than the one needed for the rigid body case which was controlled by the SPH (water) stability requirements. A solution to this problem is discussed by McGuckin et al. (2012).

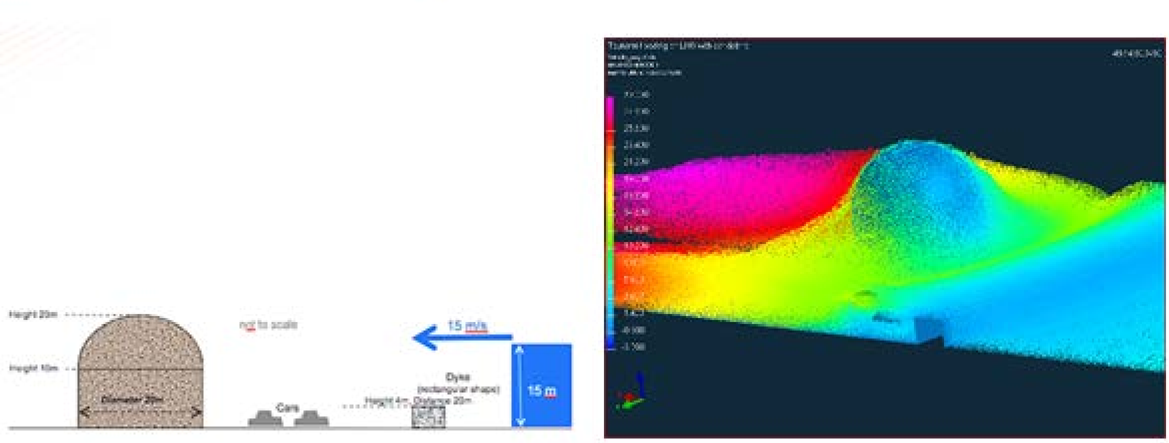

Figure 1. Layout of the model (left) and Tsunami slamming results (right).

References

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Short CV

Dr. Paul Groenenboom is Senior Physicist in the New Technologies Section from ESI-Group. He has over 25 years of experience in numerical simulation as a developer of many defense and crashworthiness oriented options within the ESI Group codes and in particular the creation and maintenance of the SPH options. He participated to several European aeronautics focused projects including CAST, CRAHVI, MAAXIMUS and SMAES (SPH simulations of aircraft ditching). His main interest is in the fluid-structure interaction predictive simulations with meshless in general and in particular with SPH. Since 2006 he has been the Dutch delegate to the SPHERIC (SPH European Research Interest Community) steering committee.