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Comparative Study of Standard WC-SPH and MPS Solvers for Free Surface Academic Problems

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Smoothed Particle Hydrodynamics (SPH) and Moving Particle Semi-implicit (MPS) are well known computational fluid dynamics (CFD) methods that are used to solve fluid dynamics problems in a meshfree Lagrangian framework. Both the SPH and MPS are well suited for simulating large deformation and the fragmentation of the free surface. They use a particle system for numerical simulation; however, there are some differences in numerical schemes and equations including differentiation, pressure calculation, and treatment of boundary conditions. The classical test cases of the particle method, two-dimensional broken dam, and harmonically oscillated sloshing tank are selected for a comparative study. The standard weakly compressible (WC) SPH parallel solver, DualSPHysics, and the in-house Moving Particle Semi-implicit solver are used in this study. For a quantitative comparison of respective viscous parameters, the broken dam problem is studied through the use of free surface snapshots. Those two numerical methods are also compared with corresponding experiments. In the case of the harmonically oscillated sloshing tank, the free-decay natural periods, sloshing impact pressure, and free surface profile are compared with the corresponding measurements. Through the comparative study, several minor differences are observed. The MPS is typically computationally more intensive in dealing with a large number of particles due to the pressure Poisson equation. In contrast, the SPH is computationally efficient, but the pressure fluctuation can be problematic when a sufficiently large number of particles are not used. Also, in the SPH, the unphysical gap between fluid particles and wall particles is observed. The relative merits of the two particle methods for solving free surface academic problems are discussed.

INTRODUCTION

The Moving Particle Semi-implicit (MPS) method and Smoothed Particle Hydrodynamics (SPH) method are computational fluid dynamics (CFD) methods that use a Lagrangian meshfree framework. SPH was first introduced by Gingold and Monaghan (1977) and Lucy (1977) and was initially developed for astrophysics applications, while MPS was first introduced by Koshizuka and Oka (1996) and was initially developed for the simulation of incompressible fluid flow. Both methods discretized the fluid continuum into finite fluid particles and utilized the weighted interpolation method to compute the physical quantities of each particle.

Both methods have several notable advantages compared to conventional grid-based methods (Chen, 2011), i.e., they have a relatively easy procedure for solving the equation of motions, trace free surfaces better when handling large domain deformation, and guarantee the conservation of mass. Both of them also suffer from the same disadvantages such as experiencing difficulties in handling diffusion and, most importantly, the high computation cost. However, along with rapid improvements in computational capabilities in the last several years, new implementations of and improvements in the SPH and MPS have emerged (Kim et al., 2014; Chen et al., 2015). Each method also has its own strong and weak points that uniquely correspond to the way in which each method is formulated.

In order to see more clearly the general behavior and the strong and weak points of each method, a comparative study needs to be conducted using the same test case with the most similar setting for each method. To achieve this, a dam break case, a free-decay test, and a forced harmonically oscillated sloshing tank case are used. A quantitative study of the leading edge of a collapsed water column and free surface representations in the dam break case is conducted, while a qualitative study of the free decay and harmonic oscillation in the sloshing tank case is conducted. An in-house program from Offshore System Simulation Laboratory at Texas A&M University in the USA is used for the MPS simulations (Kim et al., 2014), while an open source standard weakly compressible (WC) SPH solver program, DualSPHysics, is used for the SPH simulations (Crespo et al., 2015). Here, standard means that it is not necessarily the most advanced program. Both

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