Multi-DOF Water Entry of Three-dimensional Oblique Cylinder

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Abstract

Water entry is a very complex flow problem in the naval architecture and ocean engineering, which always accompanies with the slamming, the large deformation of free surface and moving boundary. Thus, numerically simulating water entry is a challenging task of researchers.

In the present work, the moving particle semi-implicit method (MPS), a fully Lagrangian particle method for incompressible fluid, is used to simulate this problem. However, most previous researches of our group focus on two-dimensional water entry problems because of huge computation time on CPU. GPU parallel acceleration technique widely used in scientific calculations is applied to improve computational efficiency of MPS. In addition, the motion function of multi-degree of freedom (multi-DOF) is developed for real three-dimensional water entry problem.

In this paper, the cylinder model with an oblique angle of $35°$ is the same as experimental model by Sun et al. in 2015. The cylinder vertically enters the still water with an initial velocity of 1.92 m/s. The motions of surge, heave and pitch are free. The simulation of whole process is carried out by our in-house slover MPSGPU-SJTU, which is developed on improved MPS and GPU acceleration technique. In the previous work by Tang et al. in 2016, only half of computational domain is simulated due to the symmetry of this problem. Because of the improvement of computational efficiency, the whole computational domain is built to capture more details of fluid flied in this work. By GPU calculation, the motions of cylinder are accurately predicted. And details of pressure field and free surface deformation can be observed by GPU simulation. The numerical results show a good agreement with the corresponding experimental data and SPH results. In addition, the computation times of one hundred steps between GPU and CPU is compared. These comparisons show that MPS method coupling with GPU acceleration technique is feasible and faster for the direct numerical study of multi-DOF three-dimensional water entry problem.

Keywords: Multi-DOF Water entry; Three-dimensional oblique cylinder; Moving particle semi-implicit; MPSGPU-SJTU solver