Simulation of Static Sinusoidal Wave in Deep Water Environment with Complex Boundary Conditions Using SPH Method

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Abstract
The study of wave and its propagation on the water surface is among significant phenomena in designing quay, marine and water structures. Therefore, in order to design structures which are exposed to direct wave forces, it is necessary to study and simulate water surface height and the wave forces on the structures body in different boundary conditions. In this study, the propagation of static sinusoidal wave in deep water environment with complex boundary conditions was simulated by using Smoothed Particle Hydrodynamics (SPH) method in various boundary conditions. After determining the suitable number of particles for simulation, the duration of sinusoidal wave oscillation was measured by simulation and was compared with analytical solution. After ensuring the accuracy of SPH method in simulation of static sinusoidal wave motion on the deep water surface, the simulation was carried out in more complex boundary conditions for which there are no analytical solutions.
Keywords: SPH method, Static sinusoidal wave, Complex boundary condition, Deep water.

1. INTRODUCTION

The Navier-Stokes equation is governing equation for many phenomena in fluid mechanics science. Although this equation is in linear form, but don't have exact solution excluding in simple problem with many assumptions. The Approximate methods which called numerical methods in computational fluid dynamics (CFD) were extended for solving the Navier-Stokes equation. Using these methods, the continuum domain of problem discretized to finite number of point or mesh. Also in numerical methods, differential equations convert to algebraic terms and employ the trial-error approach for solves converted equations. Two types of numerical methods were development; First type is mesh-base methods, which in these methods, the problem domain is discretized to finite number of mesh. The mesh is stationary and can not move in simulation progress. Second type of numerical method is mesh-less method. In this method, continuum domain of solution is discretized to number of point or particle which doesn't have specific location and can move in simulation. SPH method is one of the mesh-less method which can simulate free surface flow with large deformation and complex boundary condition in Lagrangian description [1].

Simulation of impulsive waves generated by landslides is presented in Ataei-Ashtiyani and Shobeyri (2007), Qiu (2008) and Capone et al. (2010) research. They used I-SPH method and considered landslide in two type; i.e. rigid and deformable landslide. The results prove the efficiency and applicability of the I-SPH method for simulation of complex free surface problems with wave in surface [2, 3, 4]. Yim et al. (2008) was investigated about the water wave generation by falling rigid body. They applied two different numerical approaches, RANS and SPH, for simulation the time histories of fluid motion, free surface deformation, and the vertical displacement of a rectangular-shape rigid body. Numerical solutions for the velocity fields, pressure distributions, and turbulence intensities in the vicinity of the falling rigid body are good arrangement with experimental data [5]. In the past researches, the wave motion and its propagation was simulated by SPH method in tuned liquid damper (TLD) and sloshing behavior. The shape of wave surface, water height and force in body wall was successfully determined [6, 7].

Interaction between wave and structure is importance problem in design of costal engineering structure. For design and construction of coastal structure must be considering wave height and force in structure walls. The governing equation for simulation of wave propagation in deep water environment is Navier-Stokes equation. This problem is free surface flow with large deformation. Consequently, the SPH