SIMULATING THE INTERACTION BETWEEN WAVES AND A FIXED RECTANGLE WITH OPENFOAM

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During the past few decades, two dimensional wave tank about the interaction of waves with cylinder [8, 12] or rectangular [4, 11, 13] structures have been studied. Numerical models provide a valuable tool to predict the wave-induced response of a fixed rectangle. Such a model should account for the interactions between the local wave field and the structure, such as the scattering of the waves by the structure, and the radiation of waves due to the structure motions. Furthermore, the model should account for the complex nearshore evolution of the waves as they propagate from relatively deep water to shallower water depths. This includes processes like shoaling refraction, diffraction, wave breaking, and nonlinear interactions. With the increase of computational powers, various detailed Computational Fluid Dynamics (CFD) models have been developed that can resolve the turbulent flow field in the vicinity of a floating body. Examples includes models that are based on the Reynolds-averaged Navier-Stokes (RANS) equations and models based on the Smoothed Particle Hydrodynamics (SPH) method. The use of RANS equations to model coastal engineering processes is growing in importance. One of their greatest features is the capability to obtain three dimensional pressure and velocity profiles, which allow for a more realistic treatment of all the dynamics, being capable of accurately simulating wave conditions along the while spectrum of relative water depth.

The central idea in this paper is to drive an open source CFD toolbox OpenFOAM○®[5, 7], which in Bredmose et al. [1~2] and Jasak et al.[6] has been successfully applied to calculations of waves flow over obstacles, resolves the waves around the fixed rectangle structure. The numerical solution is obtained by solving the incompressible Navier-Stokes equations in combination with volume of fluid (VOF) method [3], which is a famous surface tracking scheme. Advantages of VOF method are that it is very simple, allowing very complex free surface configurations to be represented easily and that it involves no mesh motion. In this study, the validity of the isotropic assumption is considered by using a nonlinear (NL) k-ε model developed by Shih et al. [10], which accounts for anisotropic effects by introducing a nonlinear Reynolds stress term into the standard NL k-ε model. A solitary wave pass a submerged, immersed, or floating fixed rectangle is firstly simulated (Figure 1). The numerical results are compared to the experimental data and very good agreements have been obtained for velocities in the vortex behind the structure (Figure 2). Then a three-dimensional regular wave flow over a rectangle also has been simulated and validated in this paper (Figure 3). Waves are found to be generated realistically and agreement between laboratory and numerical data is very high regarding wave breaking, run up and undertow currents (Figure 4).

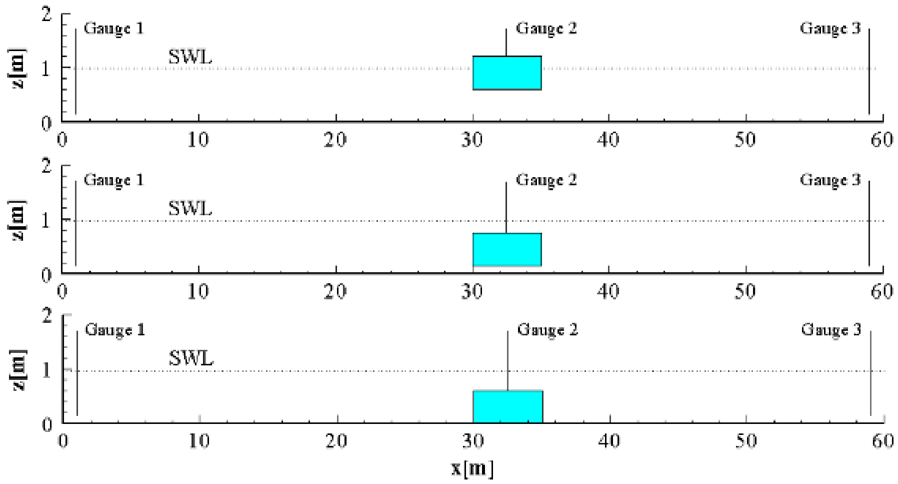

Figure 1: Schematic illustration of a solitary past a submerged, immersed, or floating rectangle

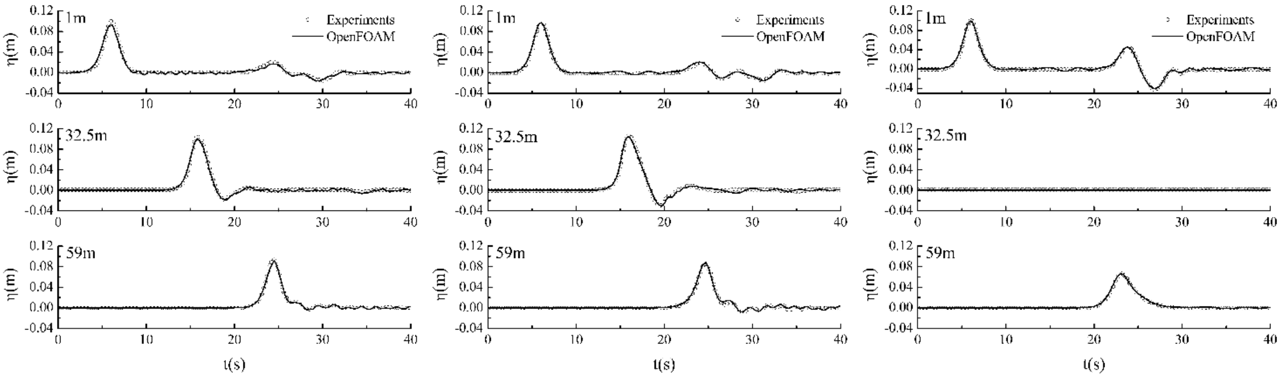

Figure 2: The comparisons of time histories of free surface displacement at x = 1 m, 32.5 m, and 59 m between experiments and OpenFOAM (left panel: submerged; middle panel: immersed; right panel: floating)

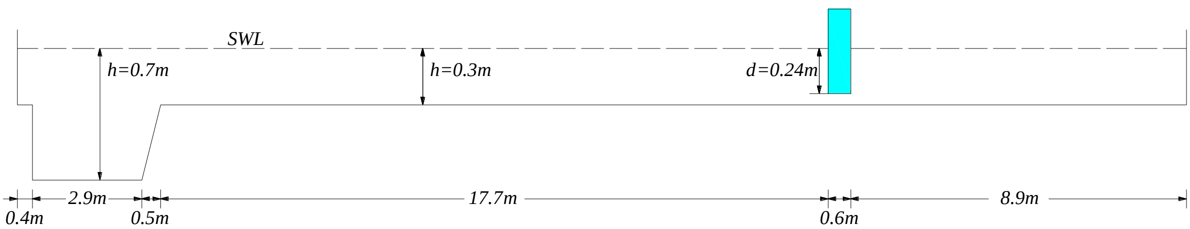

Figure 3: Schematic illustration of a regular wave past an immersed rectangle

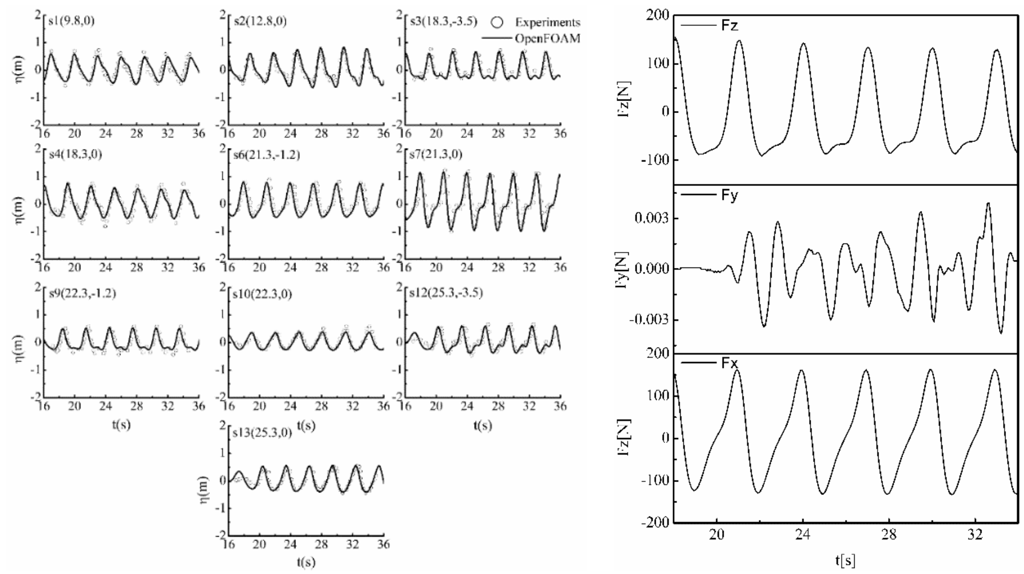

Figure 5: Time series of wave elevations (left panel) and forces on rectangle (right panel)

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References

[1] Bredmose, H., & Jacobsen, N. G. (2010). Breaking wave impacts on offshore wind turbine foundations: focused wave groups and cfd.

[2] Bredmose, H., & Jacobsen, N. G. (2011). Vertical Wave Impacts on Offshore Wind Turbine Inspection Platforms. ASME 2011, International Conference on Ocean, Offshore and Arctic Engineering (pp.645-654).

[3] Hirt, C. W., & Nichols, B. D. (1981). Volume of fluid (vof) method for the dynamics of free boundaries ☆. J.comput.phys, 39(1), 201-225.

[4] Huang, Z. (2006). Wave interaction with one or two rows of closely spaced rectangular cylinders. Ocean Engineering, 34(11), 1584-1591.

[5] http://www.openfoam.org/version2.3.0/multiphase.php.

[6] Jasak, H. and Vukčević, V. (2014). Simulation of Wave Impact Loads in OpenFOAM. 21st Symposium on Theory and Practice in Shipbuilding. Hrvatska znanstvena bibliografija i MZOS-Svibor.

[7] OpenCFD, OpenFOAM: The Open Source CFD Toolbox. User Guide Version 1.4, OpenCFD Limited. Reading UK, Apr. 2007.

[8] Paulsen, B. T., Bredmose, H., and Bingham, H. B. (2012). Accurate computation of wave loads on a bottom fixed circular cylinder.

[9] Pengzhi Lin. (2006). A multiple-layer σ-coordinate model for simulation of wave structure interaction. Computers & Fluids, 35, 147-167

[10] Shih, T. H., Zhu, J. and Lumley, John L. (1996). Calculation of wall-bounded complex flows and free shear flows. International Journal for Numerical Methods in Fluids, 23(11), 1133-1144.

[11] Sue, Y. C., Chern, M. J., & Hwang, R. R. (2005). Interaction of nonlinear progressive viscous waves with a submerged obstacle. Ocean Engineering, 32(8–9), 893-923.

[12] Teng, T. L., Pizer, D., Simmonds, D., Kyte, A., Greaves, D., & Teng, T. L., et al. (2017). Simulation and analysis of wave-structure interactions for a semi-immersed horizontal cylinder. Ocean Engineering.

[13] Venugopal, V., Varyani, K. S., & Barltrop, N. D. P. (2006). Wave force coefficients for horizontally submerged rectangular cylinders. Ocean Engineering, 33(11–12), 1669-1704.

[14] Wang Daguo. (2011). A 3D Time domain coupled model for nonlinear waves acting on a box-shaped ship fixed in a harbor. China Ocean Engineering, 25(3), 441-456.