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TURBULENCE MODELING, ABSORBING BOUNDARY CONDITIONS AND LOCAL GRID REFINEMENT FOR FREE-SURFACE FLOW SIMULATIONS IN OFFSHORE APPLICATIONS

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Extreme hydrodynamic wave impact on rigid and floating structures is of high industrial interest in offshore and coastal engineering. To study the occurring phenomena the VOF-based CFD simulation tool ComFLOW has been develeopd; see e.g. [1, 2, 3]. Over the years, several physical modeling aspects and numerical algorithmic issues have been tackled. Recently, much attention has been paid to three ingredients: turbulence modeling, absorbing boundary conditions and local grid refinement.

The grids used in ComFLOW are too coarse to resolve the turbulent details of the flow. Therefore a turbulence model is required that can cope with coarse grids, yet without excessive diffusive smoothing. Based on recent developments in turbulence modeling, a blend of a qr-model and a regularization model has been designed [4]. The grids being Cartesian, curved solid walls are treated with a cut-cell immersed boundary method, extended with a dedicated wall model (Werner-Wengle). Numerical oscillations caused by the too coarse grid are reduced by a filter.

The computational effort can be reduced by restricting the computational domain to the close environment of the objects studied. To suppress unphysical oscillations from the numerical boundaries, special generating and absorbing boundary conditions have been designed. These are based on a (first- or second-order) Sommerfeld-type condition that is combined with a Padé approximation of the dispersion relation. This combination results in a relation between the normal derivative and the second-order tangential derivative along the boundary. The approach can handle multi-directional in- and outgoing waves.

Grid resolution can be enhanced by using local grid refinement. Hereto, a semi-structured approach is used on rectangular refinement regions allowing efficient solution methods. Near refinement interfaces, special discretization stencils have been designed, as well as an adaptation of the VOF algorithm to move the free liquid surface.

The combined performance of the new ingredients will be demonstrated with two applications: run-up against a semi-submersible, and sloshing in a moonpool. For both applications, experiments have been carried out at MARIN to validate the computational results.

REFERENCES

[1] K.M.T. Kleefsman, G. Fekken, A.E.P. Veldman, B. Iwanowski and B. Buchner. A Volume-of-Fluid based simulation method for wave impact problems. *J. Comput. Phys.*, **206**, 363–393, 2005.

[2] A.E.P. Veldman, R. Luppes, T. Bunnik, R.H.M. Huijsmans, B. Duz, B. IWanowski, R. Wemmenhove, M.J.A. Borsboom, H.J.L. van der Heiden and P. van der Plas. Extreme wave impact on offshore platforms and coastal constructions. In: *Proc. 30th Conf. on Ocean, Offshore and Arctic Eng. OMAE2001*, paper OMAE2011-49488, Rotterdam (Netherlands), June 19-24, 2011.

[3] R. Wemmenhove, R. Luppes, A.E.P. Veldman and T. Bunnik. Simulation of hydrodynamic wave loading by a compresible two-phase flow method. In: D. Le Touzé (ed.) *Violent Flows 2012*. Editions Publibook, ISBN 978-2-7483-9035-3, pp. 289–296.

[4] R. Verstappen. When does eddy viscosity damp subfilter scales sufficiently? *J. Scient. Comput.*, **49**, 94-110, 2011.