Yanlin Shao¹ & Finn-Christian W. Hanssen²

Harmonic Polynomial Cell method with Immersed Boundaries

yshao@mek.dtu.dk

¹ Technical University of Denmark
² Norwegian University of Science and Technology

BCAM-Basque Center for Applied Mathematics, 3-7 April 2017
Hydrodynamics of wave energy converters

Abstract

Shao & Faltinsen (2012, 2014a) has initiated the development of a new FNPF model based on a novel harmonic polynomial cell (HPC) method. The computational domain is discretized by overlapping cells. Within each cell, the velocity potential is represented by the linear superposition of a complete set of harmonic polynomials, which are the elementary solutions of Laplace equation. The original HPC method of Shao & Faltinsen (2012, 2014a) works on structured grid and has been verified and validated by idealized cases. The structured grid has been found to limit the application of the HPC method in general wave-structure analysis. Recent development of the HPC method is focusing on handling complex structure geometries and deforming free surfaces. To achieve that, several strategies have been proposed. Among others, the immersed boundary (IB) approach has been proposed by Hanssen et al. (2015, 2017) looks more powerful in terms of modelling complex geometries.

The general idea of the IB approach is to utilize the continuous representation of the flow variable (the velocity potential) within each cell in the HPC method. In practice, we operate with ghost nodes and ghost cells, where the velocity potential is extended out of the physical computational domain. However, this has no implication for the solution inside the fluid domain. Another consequence of the HPC formulation is that it is easy to couple different solution domains directly, where communication points between grids can be considered as IBs in the respective solution regions. The figure below illustrates a practical example where the IB approach is combined with an overlapping-grid method to simulate the flow due to a heaving cylinder. To the left, an Earth-fixed background grid with a relatively coarse discretization is shown. The red square indicates the outer boundaries of the body-fixed grid, with details shown to the right. Here, boundary conditions at the body surface are taken into account in the grey-shaded ghost cells. The free surface, indicated with blue markers, is treated as an IB in both domains. In both grids, the red circles indicate communication nodes where the velocity potential from the other grid is given as a boundary condition.

The obvious advantages of the IB approach is that we can operate with structured grids that are easy to generate and that do not deform with time, even in the case of complex surface geometries. The overlapping-grid approach represents a further enhancement of the IB method, which enables grid refinement close to body boundaries without having to stretch the grid and independent of the surface’s position.
Fig. 1 The grid systems used for a semi-submerged heaving circular cylinder

(a) Background grid
(b) Body-fixed grid

References


