International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 31, No. 1, March 2021, pp. 87–94; https://doi.org/10.17736/ijope.2021.jc821

http://www.isope.org/publications

Simulation of Steep Waves Interacting with a Cylinder by Coupling CFD and Lagrangian Models

Pablo Higuera
Department of Civil and Environmental Engineering, University of Auckland
Auckland, New Zealand

Eugeny Buldakov
Department of Civil Engineering, University College London
London, United Kingdom

Dimitris Stagonas
Department of Civil and Environmental Engineering, University of Cyprus
Nicosia, Cyprus

This paper presents numerical modelling results of the interaction between a group of steep waves and a fixed vertical cylinder performed with a one-way coupled hybrid model. A set of experimental data is used to benchmark the accuracy of the modelling results. The wavemaker signal generated in the physical experiments is used to reproduce the incident wave conditions without a priori knowledge of the rest of the dataset. A Lagrangian numerical wave flume propagates the wave group, producing the nonlinear free surface elevation and wave kinematics with high accuracy in the vicinity of the cylindrical structure. This data is used as the input to the *olaFlow* CFD model, which calculates the wave–structure interactions. One-way coupling approaches based on boundary conditions and relaxation zones are tested and compared in terms of the recorded free surface elevation and pressures at the structure. The results present an adequate degree of accordance, and turbulence effects are found to be negligible in the simulations.

INTRODUCTION

Wave and structure interaction (WSI) is a field in which numerical modelling is being applied consistently and with increasing popularity. The challenges derived from modelling the impact of waves and structures are numerous. Marine and offshore structures are usually located in areas subjected to extremely harsh conditions, in which waves often present three-dimensional and highly-nonlinear processes such as wave breaking, and wave impacts may result in impulsive loading.

Under such conditions, the relevance of numerical modelling, and especially computational fluid dynamics (CFD), derives from the low number of underlying assumptions involved with the Navier–Stokes equations, from their inherent nonlinearity and from their capability to include turbulence dissipation effects via Reynolds-averaged Navier–Stokes (RANS) or Large Eddy Simulation (LES) turbulence models. Furthermore, despite its advantages and flexibility, numerical modelling results alone have limited practical credibility if they are not accompanied by a reasonable validation against experimental measurements, which is why physical and numerical modelling should be deemed as complementary approaches.

Another of the limitations of CFD is the large computational cost required, which makes it an impractical approach to simulate extensive domains and long time series. Instead, hybrid modelling (HM) appears to be gaining momentum to reduce such limitations. The concept behind HM consists of simulating the different areas of interest with several numerical techniques, according to the complexity of the processes occurring within each one. For example, under certain circumstances, wave propagation can be accurately simulated with a potential flow theory model instead of using CFD, thus saving a significant amount of computational resources and time. The potential flow theory modelling may be performed until close to the structure of interest, where the CFD model calculations would take over to simulate the detailed interactions (e.g., Lachaume et al., 2003; Kim et al., 2010; Guo et al., 2012).

There are two principal approaches to link the numerical models. In one-way coupling, one of the models is first run independently from the other, and the data are passed to the second one, so there is no connection of feedback loop between the models. In two-way coupling, both models are run concurrently, and they exchange information at the interface (which can be a boundary or a region in space). This way, waves could ideally propagate across models seamlessly. Despite being a more complete and realistic approach, two-way coupling models present significant technical and numerical implementation challenges, for example, in terms of blending solutions from two sets of equations.

In this paper we introduce a one-way coupling HM approach between Lagrangian and CFD models. The Lagrangian model propagates the wave group and generates the dataset of wave kinematics to feed the CFD model using the displacement of the physical wavemaker as only input. Then, the CFD model reproduces the incident wave conditions via a boundary condition and a relaxation zone without additional tuning.

This paper is structured as follows. The physical experiments are described after this introductory chapter. The Lagrangian

Received September 27, 2020; updated and further revised manuscript received by the editors January 26, 2021. The original version (prior to the final updated and revised manuscript) was presented at the Thirtieth International Ocean and Polar Engineering Conference (ISOPE-2020), Shanghai, China, October 11–16, 2020.

KEY WORDS: Wave–structure interaction, cylinder, Lagrangian wave model, *olaFlow*, OpenFOAM.