Numerical Simulation of Wave Run-up around a Vertical Cylinder

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ABSTRACT

Wave run-up and wave impact cause unexpected damage to the offshore platforms. To design a platform against wave impact one must accurately estimate the wave scattering around large volume structures and the maximum run-up height. In this study, simulations of the wave run-up around a fixed vertical cylinder are conducted. The finite volume method (FVM) is employed for solving Navier-Stokes equations based on the open source codes of OpenFOAM. The wave elevations within a radial distance around the cylinder are monitored at several locations. The maximum run-up height is measured, and also the flow field is investigated including the velocity and pressure distributions. The obtained results of wave run-up and scattering around the cylinder are compared with published experiment data. The results show the efficiency of the present numerical method for simulating wave run-up problems, and also provide useful guidance for designing platforms.

KEY WORDS: Wave run-up; cylinder; numerical wave tank; OpenFOAM.

INTRODUCTION

Wave run-up and wave impact can cause unexpected damage to offshore structures. Therefore, the design of offshore structures requires accurate predictions of the maximum wave elevation to maintain sufficient airgap below the platform deck. Accurate prediction of wave run-up can both help reducing building costs and avoid the risk of wave impact and damage to the platform. For the increasing number of offshore platforms built for ocean oil and gas exploration, the investigation of wave run-up becomes more and more significant for the design of fixed offshore structures.

Wave run-up on circular cylinders has been studied experimentally and numerically in the past decades. Niedzwiecki & Duggal (1992) performed a small-scale experiment to study the wave run-up on a truncated circular cylinder. Martin et al. (2001) investigated run-up on columns caused by steep, deep water regular waves and concluded that linear diffraction theory was inadequate. Experiment investigations were also carried out by Mase et al. (2001) and De Vos et al. (2007), and empirical formulas were given to predict the wave run-up. Based on the experiments performed by MARINTEK (Nielsen, 2003) and Morris-Thomas & Thiagarajan (2004), a series of experimental data was published. The model test performed at MARINTEK was proposed as the ISSC benchmark study. The wave run-up results obtained by different numerical methods were proposed and compared with the MARINTEK data.

In previous works the focus has been the horizontal forces, whereas the wave run-up has been studied in less detail. With the linear diffraction theory, the approximate run-up ratio function was given, e.g. in MacCamy & Fuchs (1954) and Haney & Herbich (1982). Linear diffraction theory predicted that run-up height is a function of the scattering parameter \( \kappa a \), where \( \kappa \) is the wave number and \( a \) is the cylinder radius. Kriebel (1990, 1992) presented the solution of the nonlinear wave–cylinder interaction and predicted that the solution of linear diffraction theory was under-predicted for run-up in larger waves.

With the development of numerical techniques, time domain simulations became an alternative for wave run-up and wave-structure interaction problem. Buchmann et al. (1998) used a second-order boundary element model for the wave run-up problem. Trulsen & Teigen (2002) applied the fully nonlinear potential method for computing the wave scattering around a vertical cylinder. Lee et al. (2007) simulated the wave run-up on vertical cylinder by a 3-diensional VOF method based on a two-step projection, and discussed the nonlinear wave-cylinder interaction. Dannmeier et al. (2008) compared the wave run-up results from a second-order diffraction code (WAMIT) and a fully nonlinear CFD program (ComFLOW) with the experiments.

In recent years, lots of commercial CFD software has been employed for solving the wave-structure interaction problem such as Fluent, CFX, Flow-3D, etc. However, for commercial interests, the source codes of these commercial packages are not open to the user, which has restricted the development of CFD methods. The Open source Field Operation and Manipulation (OpenFOAM) C++ libraries provide users the open source codes for developing new CFD methods. The user can not only use OpenFOAM as software, but also can modify all the codes of OpenFOAM, even create new solvers and numerical schemes for particular problems. The object-oriented C++ programming language lays a good basis for the development of OpenFOAM, as well as the development of CFD.

In the present study, simulations of wave run-up on a fixed cylinder are conducted by employing the Finite Volume Method (FVM) to solve the Navier-Stokes equations based on the open source codes of OpenFOAM.