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CFD Application to the Evaluation of Wave and Current Loads on Cylindrical Platform Model for Ocean Wind Turbine

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ABSTRACT

Numerical simulations were performed for the evaluation of wave and current loads on fixed cylindrical platform model for ocean wind turbine using ANSYS-CFX package. The numerical wave tank was actualized by specifying velocity at the inlet and applying momentum loss as wave damper at the end of the wave tank. Volume-Of-Fluid (VOF) scheme was adopted to capture the air-water interface. Accuracy validation of numerical wave tank with truncated vertical circular cylinder had been accomplished by comparing the CFD results with Morison’s formula and the experimental data. The parametric study has been carried out by varying the wave length and amplitude alternatively. As a meaningful engineering application, in the present study, three kinds of conditions have considered, i.e. the cases with current, waves and the combination of current and progressive wave, respectively, passing through a cylindrical platform model. It was found that CFD results show reasonable agreement with experimental data and Morison’s formula when only progressive wave is considered, however, when current is included, CFD gives smaller load than Morison’s formula.

KEY WORDS: Numerical wave tank; wave load; current load; circular cylinder; OWT; Morison’s formula.

INTRODUCTION

Wind turbine foundations installed at offshore sites are subject to ocean waves and current directly. Recently the structural integrity of Ocean Wind Turbine (OWT) foundation draws much attention as renewable wind energy market grows. As the main component to the wind turbine system, cylindrical foundation has been widely used. Flow around circular cylinders has been a research topic in fluid mechanics for decades because of its complex physical phenomena, such as separation and vortex shedding, deformation of incoming wave. The study on the harmonic oscillatory flow around a circular cylinder is of importance for the estimation of wave and current load. For a planar oscillatory flow around a circular cylinder, there are many experimental and numerical studies, providing the basic knowledge to further understand complex flow environments, such as the combination of oscillatory flow by incoming wave and current-induced vortex shedding.

It is common that the in-line force F_x on a circular cylinder in waves can be written as the sum of wave inertial forces and viscous drag, known as Morison's formula (Morison *et al*. 1950). Weggel *et al*. (1996) offers a wave load and response model for a cylinder in deep water, using the second-order potential theory. A weakly nonlinear diffraction on a vertical truncated cylinder was investigated by Boo (1995) in a numerical wave tank, where the body boundary condition was exact, but the linear free surface condition was imposed. Recently, fully nonlinear interactions in regular and irregular waves studied by Boo (2002). There were some CFD applications (Dong and Huang, 2001; Park *et al*., 2001) to establish numerical wave tank which solve the Navier-Stokes equations other than potential-based Laplace equation. It seems that the CFD method provided flexibility in modeling and simulations, however, the computational cost would be much bigger.

First of all, in the present study, a numerical wave tank was actualized to generate progressive regular wave acting at the fixed cylindrical cylinder. The velocity components in both horizontal and vertical directions were given at the inlet of numerical wave tank, based upon Airy’s linear wave theory. In addition, the so-called isotropic momentum loss model supported in ANSYS-CFX package was adopted to damp out residual wave energy far downstream, preventing the wave reflection at the end part of numerical wave tank. The interface capturing method using the VOF method (Hirt and Nichols, 1981) was used to simulate wave propagation in the numerical wave tank for each time-step. In the next, for the efficiency validation of numerical method, wave load on a truncated cylinder was calculated and compared with Morison’s formula and experimental data carried out in MOERI (Sung et al., 2007). CFD simulation seems to give a good agreement with experiment, when the wave steepness is relatively small. Finally wave and current loads on a fixed circular cylinder were calculated with both incoming wave and current being taken into account.

GENERATION OF NUMERICAL WAVE TANK

Geometry and mesh topology

Numerical wave tank was actualized to estimate the forces of progressive regular waves on the fixed circular cylinder. The horizontal and vertical length of 2D numerical wave tank is of 7m and 3m, respectively. Water depth is of 2m. Geometry and meshing were done using ICEM-CFD. Fine mesh was created near the free surface for the more accurate movement of free surface. About 55,000 grids were used in 2-D tank. Geometry and grid system of the numerical wave tank are