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Numerical Predictions of Wave Impacts on the Supporting Structures of Shanghai Donghai-Bridge Offshore Wind Turbines

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ABSTRACT

Nowadays, the development of offshore wind energy technology has received considerable attention worldwide. In this paper, numerical investigation of wave run-up and wave forces around the supporting structure of a wind turbine in Shanghai Donghai-Bridge offshore wind farm by using our own CFD code naoe-FOAM-SJTU (Shen, Cao and Wan, 2012) is presented. The naoe-FOAM-SJTU solver is developed based on OpenFOAM and employs the finite volume method (FVM) to solve RANS equations, the free surface is tracked by volume of fluid (VOF) method. Two different big waves are investigated. The values of wave run-up around the supporting structure are measured and total forces on the individual piles due to wave run-up are calculated. Meanwhile, the flow field including velocity and pressure distributions is analyzed. The results show strong nonlinear character, and the phenomenon of green water on bearing platform is observed. The numerical results can help to understand the run-up phenomenon of Donghai-Bridge offshore wind turbine foundations and to provide some guidance to the design of the new supporting structures of offshore wind turbines.

KEY WORDS: Offshore wind turbine; supporting structure; wave impacts; numerical simulation; naoe-FOAM-SJTU solver.

INTRODUCTION

Since serious health and environmental problems caused by the excessive use of fossil fuels have been gradually revealed in recent years, more attention are paid to new energy which are clean, recycle and renewable to meet the energy needs of society. There are different kinds of renewable energy source, such as solar energy, wind energy, wave energy, etc. Among all these forms, wind energy, to some extent, has become the fastest growing form of renewable energy, which was stated by Sun *et al.* (2012). As more and more advantages of offshore wind turbine have been found, the development and research pace of offshore wind energy is accelerating rapidly and takes hold of the world's attention. In comparison to onshore wind farms, offshore wind farms have numerous advantages that are unmatchable for traditional wind farms. First and foremost, due to few obstacles, wind speed over water is generally higher, more consistent and smoother than that over land. So the wind energy available is much greater. Secondly, offshore wind farms are far away from the place of residence, there therefore exist fewer complaints about the noise made by wind turbines and the visual impact on environment. Besides, it will save large amounts of precious land and will help ease pressure on power supply with low transportation cost in coastal areas which are the most economically developed with high demand for power.

Most of the recent foundations of offshore wind turbine are monopiles, tripods, gravity based structures, etc. According to the report released by European Wind Energy Association (2012), among the various substructures types, monopile foundations remain the most common form for their structure simplicity and installation convenience. However, when many specific factors are taken into consideration, such as the depth of relative shallow water and complicated soft soil, the foundation of grouped high-piled concrete bearing platform based on China's home-grown technology innovation is chosen for Shanghai Donghai-Bridge offshore wind farm, the first large scale offshore wind power demonstration project in China and even Asia.

To design the foundation of an offshore wind turbine, wave impacts, including impact force, run-up, wave scattering etc. are the most important factors that need to be considered carefully. For instance, wave run-up of substructures can affect the design of boat landing and the offshore wind turbine structures' platform facilities. Because of the specificity and complexity of Donghai-Bridge foundation and relative shallow water, traditional potential flow method can hardly accurately estimate the wave run-up and wave forces on it, especially the impacts of green water and impact forces on individual piles.

In recent years, with the development of offshore wind turbine, many efforts have been made to apply the Reynolds-Averaged Navier-Stokes (RANS) method to simulate wave impacts to offshore wind turbine foundations and fully non-linear flow features around them. A systematic overview of the previous and recent research about wave impact forces and the key issues concerning offshore wind turbine foundations can refer to Chella *et al.* (2012). Christensen *et al.* (2005) used CFD method with a sloping bottom initiating wave-breaking to study the extreme wave forces and wave run-up on foundations and found that the wave breaking process had a major influence on the run-up and wave forces. The prediction of breaking wave impacts on the offshore wind turbine inspection platforms using second-order focused wave group technique to generate wave and VOF method to capture free surface was conducted by Bredmose and Jacobsen (2011). The results show the impacts on monopile such as slamming pressures from wave front in details. To accurately model the strong non-linearity of