Proceedings of the Twenty-fourth (2014) International Ocean and Polar Engineering Conference **www.isope.org**
Busan, Korea, June 15-20, 2014
Copyright © 2014 by the International Society of Offshore and Polar Engineers (ISOPE)
ISBN 978-1 880653 91-3 (Set); ISSN 1098-6189 (Set)

Numerical Study of Motion Response of Floating Body in Extreme Wave

Hongjian Cao, Decheng Wan
State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering
Shanghai Jiao Tong University, Shanghai, China

ABSTRACT

Numerical study of the strongly nonlinear extreme wave interaction with a floating structure based on the open source package OpenFOAM is presented. The numerical solver is based on the Navier-Stokes equations, and the Volume of Fluid (VOF) method is employed to capture the complicated free surface. A two-dimensional numerical wave tank is established, which can generate various types of waves by given the free surface position and the water particles velocity at a fixed boundary according to wave theories. By means of the 6 degree-of-freedom (6DoF) motion solver and the deformed mesh technique, the simulation of body motion is achieved. The linear waves and focused wave are generated and compared with theoretical results to validate the numerical wave tank firstly, and then the strongly nonlinear wave-structure interaction is simulated. The motion responses of the floating structure under extreme wave are predicted. Both the motion responses of structure and the complicated free surface are compared with corresponding experimental measurements and show satisfactory agreements. The flow field and the green water phenomena are analyzed based on the numerical results. It implied that the present numerical model is efficient and accurate for dealing with the strongly nonlinear wave-structures interaction problem with both the violent free-surface flow and large amplitude body motion.

KEY WORDS: Motion response; floating body; extreme wave; green water; OpenFOAM; naoe-FOAM-SJTU solver.

INTRODUCTION

Extreme waves can cause severe damages to the offshore platforms and ships due to its large suddenly appearance and large wave amplitude. In recent years, the numerical simulation has become an important mean for studying the extreme wave generation, evolution and interaction with structures. The wave focusing approach is used mostly in previous experimental work in physical wave tank, such as Baldock and Swan (1996), Pelinovsky et al.(2000), Kriebel and Alsina (2000), Clauss (2002). As the wave components of a wave group have specified phases making their wave crests occur at the same point and at the same time, a freak wave is generated. The similar way is also applied to generate extreme wave in numerical wave tank, such as that Brandini and Grilli (2001) performed the simulation of freak waves based on higher-order boundary element method. The similar works are also performed by Bai and Eatock Taylor (2007), Zhao (2008), Ning et al.(2008), which are based on the potential flow assumption. These numerical models show great efficiency with less computation for the simulation of non-breaking waves. However, they cannot simulate the full process of the wave breaking. Moreover, when dealing with the problem of wave-structure interaction, the fluid viscosity becomes so significant that will affect the flow field and the motion of the floating structures because there will be vortex shedding from the structures surface.

In recent years, the viscous numerical models based on solving Navier-Stokes equations are employed for most of the hydrodynamic problems involving complicated free surface evolution and strongly nonlinear wave-structures interactions. Meanwhile, proper free surface treating methods such as the Volume of Fluid (VOF) method, Level Set method, Constrained Interpolation Profile (CIP) method and etc. are applied together. Numerous work has been performed to study the wave-structures interaction and predict the wave loading and motion response of structures by using the incompressible two-phase Navier-Stokes solver. Kleefsman et al. (2005) studied the wave impact and green water loading on fixed structures by using the VOF method with a cut-cell method on fixed Cartesian grid. Yamasaki et al. (2005) studied the green water impact on fixed and moving bodies using the Finite Difference Method (FDM), and the density function method was employed in the framework of a locally refined overlapping grid system. Hu et al. (2006) simulated the strongly nonlinear wave-body interaction by Constraint Interpolation Profile (CIP) based Cartesian grid method. Zhao and Hu (2012) studies the floating body motion under extreme wave conditions with CIP method, and performed the experimental test for a validation. All the works base on incompressible viscous two-phase numerical model show their powerful capability for dealing with problems involving strongly nonlinear wave-structure interaction and complicated free surface evolution

This paper presents the simulation of extreme wave interaction with a floating body with the in-house solver naoe-FOAM-SJTU, which is developed based on the open source code library OpenFOAM. The naoe-FOAM-SJTU solver has some important modules: One is a viscous numerical wave generator module, which can generate various types of waves by given the free surface position and the water particles velocity at a fixed boundary according to wave theories. Another is the six degree-of-freedom (6DoF) body motion module, which can simulate the free motion or prescribed motion by combining with the deformed mesh technique. In addition, a mooring system module is also under development for dealing with the hydrodynamic problems involving moored structures. Lots of previous works were conducted based on the naoe-FOAM-SJTU solver such as Cao et al. (2011), Cao