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Numerical Prediction of Wave Loading on a Floating Platform Coupled with a Mooring System

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ABSTRACT

Accurate predictions of wave loads and motion response of floating structures are of great importance and closely related to their safety under sea wave conditions. This paper presents numerical predictions of wave loads on a floating TLP platform coupled with a mooring system by our viscous hydrodynamic solver naoe-Foam-SJTU, which has combined the numerical wave tank module, mooring system module and 6 degree-of-freedom (6DoF) motion module. In the simulations, the wave loads are calculated as well as the nonlinear motion responses. The surge, heave and pitch motions are mainly considered under different incident regular wave conditions and with different mooring line configurations. The obtained results illustrate that the wave loads have most influence on the surge motion of the moored TLP compared to the heave and pitch motions. In addition, the free surface elevation and wave run-up phenomenon near the TLP are also presented to give a better understanding of the process of wave-structure interaction. It is indicated that the presented naoe-Foam-SJTU solver is capable of dealing with the nonlinear wave-structures interaction problem with both the free-surface and body-motion taken into consideration, therefore will be an efficient tool for solving ocean engineering problem and provide helpful guidance for the design of offshore structures.

KEY WORDS: Wave loads; floating platform; mooring system; 6DoF motion; naoe-Foam-SJTU solver.

INTRODUCTION

Marine structures are commonly utilized to undertake activities in offshore engineering fields, such as the exploration, storage, and transportation of oil and gas. With the activities moving into deeper and deeper waters, the structures will suffer harsher marine environment. Meanwhile, with the water depth increasing, most of the platforms are semi-submersed and equipped with mooring system, whose stability will be greatly influenced under large wave conditions. Therefore, the accurate predictions of wave loads and the motion response are of great importance and closely related to the safety of marine structures.

Numerous different types of platforms have been developed for the exploration of natural sources in deep water, such as FPSO (Floating Production Storage and Offloading), TLP (Tension Leg Platform), SPAR platforms and so on. Among these structures, the TLP displays good heave performance, which has attracted widespread attention of researches and engineers. A lot of works have been done previously to study the wave loads and motion response of the TLP. Liu *et al.* (1995) investigated the secondary wave loads on the typical ISSC TLP under regular wave conditions. Paik and Roesset (1996) applied the high-order nonlinear transfer functions to predict the dynamic response of a TLP. Teigen and Niedzwecki (1998) conducted both the numerical and experimental studies on a four column mini-TLP. Bhattacharyya *et al.* (2003) also made numerical and experimental studies on the mini TLP. Chandrasekaran and Jain (2002) presented the dynamic behavior of square and triangular offshore TLPs under regular wave loads. Chandrasekaran *et al.* (2007) studied the influence of wave approaching angle on the motion response of TLP. Low (2009) presented a frequency domain approach for the uncoupled analysis of a TLP in 6DoF (six degree-of-freedom) with the statistical linearization of the restoring forces. However, the tethered buoyant compliant structures can be better idealized using a coupled procedure using the finite element method (FEM). In addition to the motion characteristics, a designer is usually also interested in the structural response. Chatterjee *et al.* (1997) used coupled finite element analysis to yield the structural response simultaneously with the platform response. Natvig and Johnsen (2000) indicated that the use of coupled analysis can greatly improve the fatigue life estimates of tethers.

With the rapid development of CFD techniques, several commercial softwares, such as FLUENT, FLOW-3D, etc., have been developed and utilized for analyzing wave interactions with offshore platforms and other structures. In addition, many in-house codes have also been applied to solve the wave-structures interaction problems, such as the second-order diffraction wave hydrodynamic code WAMIT developed by M.I.T, and the numerical codes named COUPLE was introduced in Chen *et al.* (2006). In recent years, open source codes have become more and more popular, OpenFOAM is among the best. OpenFOAM is an object oriented C++ codes library for solving various partial differential equations using finite volume method. It includes pre-processing, post-processing tools and specialized CFD solvers. Not only the features of OpenFOAM are comparable to commercial CFD codes, it also provides a perfect general and open platform for developing new numerical methods and tools.

In order to provide accurate predictions of the wave loads on a floating TLP and its motion response, the naoe-Foam-SJTU solver is developed, which is based on the open source code package - OpenFOAM, and integrates the RANS-VOF model, 6DoF motion module and a numerical wave tank (NWT). In the NWT, various types