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ScienceDirect
Journal of Hydrodynamics
2008,20(1):30-38
sdlj.chinajournal.net.cn

THEORETICAL RESEARCH ON HYDRODYNAMICS OF A GEOMETRIC SPAR IN FREQUENCY- AND TIME-DOMAINS*

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(Received April 20, 2007, Revised September 7, 2007)

Abstract: Considering the coupling effects of the vessel and its riser and mooring system, hydrodynamic analyses of a geometric spar were performed both in frequency- and time-domains. Based on the boundary element method, the 3-D panel model of the geometric spar and the related free water surface model were established, and the first-order and second-order difference-frequency wave loads and other hydrodynamic coefficients were calculated. Frequency domain analysis of the motion Response Amplitude Operators (RAO) and Quadratic Transfer Functions (QTF) and time domain analysis of the response series and spectra in an extreme wave condition were conducted for the coupled system with the mooring lines and risers involved. These analyses were further validated by the physical model test results.

Key words: geometric spar, hydrodynamics, coupled analysis, frequency domain, time domain

1. Introduction

Spar platforms are mainly used in the sea areas of 500 m-3000 m water depth. Since the first installation of the Oryx Neptune Spar in the Gulf of Mexico in 1996, the spars have been increasingly popular due to their high stability, excellent motion performance and low cost of construction and maintenance. By far, as many as 14 spar platforms have been fabricated and applied in different regions of the world and they have become efficient facilities in deepwater oil and gas exploitation [1]. Along with the further development of the ocean engineering technology, the spar platforms are moving towards a period of flourish.

In the early stage of spar platform development, two basic generations of spar platforms, which are respectively classic spar and truss spar, were proposed successively [2]. Moreover, during the recent years, some new concepts of spar platforms have been put forward, such as the geometric spar [3], cell spar[4] and cell-truss spar[5]. The concept of geometric spar was proposed by Novellent Offshore LLC of USA. It combines some good qualities of the classic spar and truss spar designs, and it is hoped that improvement on motion performance and reduction in installation cost would be achieved. The model test of the geometric spar was conducted in the State Key Laboratory of Ocean Engineering at Shanghai Jiaotong University for its hydrodynamic performance [6].

The geometric spar has a unique configuration which is different from other types of spar platforms. In order to make a deeper research on this concept theoretically, a 3-D hydrodynamic vessel model with the mooring system and risers included is created, and numerical simulation of its wave loads and motion responses in a specified wave condition is carried out with the commercial program SESAM. The mooring lines, risers and the main body of the platform are regarded as a whole coupled system[7,8]. The

*Project supported by the National High Technology Research and Development Program of China (863 Program, Grant No. 2006AA09A107), the Key Fundamental Research Project of Science and Technology Commission of Shanghai Municipality (Grant No. 05DJ14001).

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frequency domain first-order Response Amplitude Operators (RAO), wave excitation forces, added mass, damping coefficients, second-order Quadratic Transfer Functions (QTF), and responses in time series in the wave of 100 year return period storm in the Gulf of Mexico are simulated and calculated. The calculated results are analyzed and compared with the model test results, thus the hydrodynamic performance of the geometric spar can be obtained.

2. Specification of the geometric spar

The remarkable characters of the geometric spar are the hull geometry and the Integrated Buoyancy Can(IBC). An octagonal cross-section of the deep draft caisson is adopted in the geometric spar instead of the cylindrical ones of conventional spars, and a concept of IBC is put forward and used instead of the traditional single buoyancy cans.

The hull of the geometric spar has an octagonal cross section with a square moon-pool, and 13 heave plates are disposed with a vertical distance of 10.7 m at every other corner of the octagon to form a square. 4 helical strakes are added around the upper outside of the hull to reduce vortex induced vibration of the platform. 8 legs are placed on the top of the hull to support upper decks.

IBC is a single, submerged buoyant hull in place of several individual buoyancy cans. The IBC hull acts as an independent floating structure, sheltered from waves and current, to provide buoyancy for riser support. A fender system consisting of 24 single fenders is fixed on the inner hull to limit the lateral mutual movements and impacts between the spar hull and IBC, so as to protect them from collision damage. A truss structure supports the dry trees above the waterline and a system of TLP type tensioners compensates for the limited, relative displacements between the IBC and risers. The capacity of the IBC can be increased by removing the vertical and horizontal gaps that exist between individual buoyancy cans to employ the entire well bay to produce buoyancy.

The configuration of the geometric spar is shown in Fig.1.

The design water depth of the geometric spar is 1219 m. In order to keep the spar in the designed in-place position, a mooring system comprised of 12 mooring lines with a chain-wire-chain combination is used. The mooring lines are divided into 4 groups and hang on every other side face of the octagon hull. The fairlead location above the keel is 76.2 m. The coupled system consists of spar hull and deck, IBC, mooring lines and risers, as shown in Fig.2.

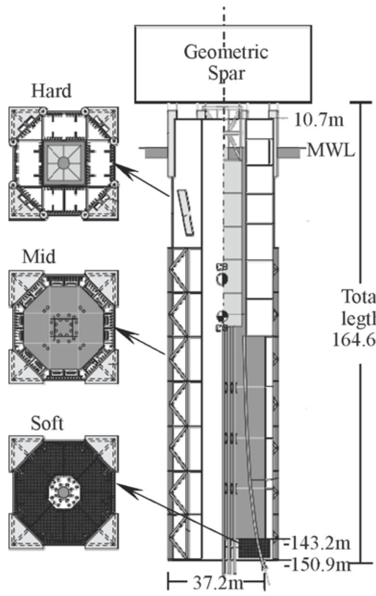

Fig.1 Configuration of the geometric spar

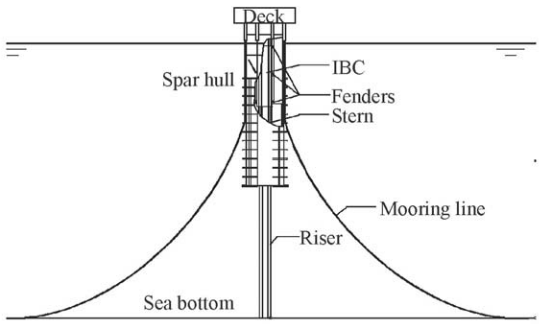

Fig.2 The coupled system (with distorted scale of water depth)

3. Description of the moedl test

The model test was carried out in the ocean basin of the State Key Laboratory of Ocean Engineering at Shanghai Jiaotong University, and the linear scale ratio λ between the prototype and the model was chosen to be 70[9]. The models of the spar and IBC were accurately fabricated according to the linear scale ratio within a maximum dimensional tolerance of 1%. The hull model was ballasted in the wave basin to achieve the accuracy at the location of the center of gravity of at least 1% and in the radii of gyration for pitch, roll and yaw of at least 3%. The photo of the physical models is given in Fig.3.

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