Dynamic Analysis of Truncated Mooring Lines Using Numerical Simulation and Model Tests

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ABSTRACT
This work presents 1:100 scale model tests of a semi-submersible platform with a 1500m full-depth mooring system conducted model test in the Joint Laboratory of Wind Tunnel & Wave Flume at the Harbin Institute of Technology. A truncated mooring system with the water depth of 400m designed that ensures the static restoring force characteristics of the full-depth mooring system are retained.

A numerical simulation of the mooring line dynamics is executed in the time-domain based on the non-linear finite element method to determine the differences in the dynamic behavior of the full-depth mooring line and truncated mooring line. The energy dissipated by a mooring line as a result of its oscillation is applied to calculate the damping of the mooring line under regular oscillations. The top-tension spectrums of the truncated mooring line model and the corresponding full-depth mooring line are compared under irregular oscillations to ensure similarity under realistic sea conditions.

The tensions of a mooring line were recorded when the semi-submersible platform was oscillated under regular or irregular wave excitation in the horizontal plane. The semi-submersible platform was model tested at selected regular wave excitations. The period of wave excitation changed from 6 seconds to 60 seconds and three different heights were used at each period. Finally, the semi-submersible platform was model tested under 10 year wave conditions for the South China Sea.

KEY WORDS: truncated mooring line; dynamic analysis; numerical simulation; model test

INTRODUCTION
As the oil industry is now increasingly concentrating their efforts and activities in deeper water, suitable floating platforms such as semi-submersible platforms, TLP platforms and Spar platforms are becoming more widespread. During the design stage, a vital concern is how to accurately predict the motions of floating platforms under various complicated loads in the deep sea. Presently, there are two common approaches - numerical simulation and physical model testing. A number of assumptions and/or empirical data are introduced into numerical simulation, and the simulation results can be debated or, at worst, inaccurate. Currently, the physical model test can be considered as the most precise method in the prediction of floating platforms motions under environmental load.

Other than TLP platforms, which use tension legs in the vertical direction to moor the upper floating platform, other offshore platforms all use outspread mooring system such as the traditional catenary mooring system and the recently developed taut mooring system as sketched in Fig.1. During the model testing procedure, these two kinds of mooring systems occupy large space and the intact model test can’t be accomplished in the current wave basins when adopting the scale applied in the modeling of the upper platform. It seems that the most realistic alternatives at hand will require the use of hybrid testing or hybrid verification in some form (Stansberg et al., 2002). It’s the sort of experimental technique which combines numerical simulation and truncated physical model test. Before the experiment, owing to the limitation of wave basin scale, the mooring system scope is truncated according to static equivalence firstly. The truncated mooring system is modeled by some numerical method, and then the mooring system is carried out by the standard reduced scale consistent with the upper platform. The motions and tensions are both considered during this procedure. The International Towing Tank Conference (1999) has discussed and generalized the research work on deepwater experimental tests, and the hybrid testing method is recognized as the most promising method to solve the problems in deepwater model tests. Recently, a number of scholars have achieved some results using the approach (Stansberg et al., 2000; Rolf et al., 2004; Hong et al. 2004). The two key challenges in this approach are how to design the truncated mooring system and analyze the difference of the dynamic characteristic between truncated mooring line and the corresponding full-depth mooring line.

Luo et al. (2003) introduced a method for preliminarily confirming the equivalence of the truncated mooring system. Su et al. (2006) have researched the equivalent design of the vertical and horizontal truncated mooring systems and the static equivalent design of a Spar platform mooring system. Chen et al. (2000) studied the difference between the truncated and corresponding full-depth mooring line model using...