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Hull/Mooring Coupled Dynamic Analysis of a Truss Spar in Time Domain

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ABSTRACT

Nonlinear hull/mooring coupled dynamic analysis of a truss spar in waves with collinear steady winds and currents is numerically carried out in the time domain and the results are compared with 1:61-scale experiments as well as uncoupled analyses. The first- and second-order wave forces, added mass and radiation damping, and wave drift damping are calculated from a second-order diffraction/radiation hydrodynamics program. The total wave force time series is generated based on a 2-term Volterra series model. The hull/mooring coupled dynamics are then solved using a time-domain 3D mooring dynamics program based on a generalized-coordinate-based finite element method. The mooring lines are coupled to the platform through generalized springs and dampers. A case study was conducted for the Marlin truss spar with 9 taut mooring lines in 3240-ft (988-m) water depth. The numerical results show that dynamic effects are very important for the present mooring design. The motion and tension spectra of uncoupled analyses with a linear massless spring or nonlinear massless spring are also compared with those obtained from fully coupled analysis to assess the importance of hull/mooring coupling and mooring-line damping.

INTRODUCTION

The deep-draft cylindrical spar has been shown to be an efficient platform for deepwater production, drilling, and storage (Glanville et al., 1991). Its deep draft gives it excellent motion characteristics even in the most severe sea states, which has been proved through numerical simulations, model tests and field observation. The relevant theory and comparison with experiments for this kind of spar are reported in Ran et al. (1996), Mekha et al. (1995), Cao and Zhang (1996), Kim et al. (1997) and Ran and Kim (1997). Recently, an alternative shallower-draft truss spar received considerable attention as a more economical design (Halkyard, 1996), especially in a loop-current environment. The upper part of the truss spar consists of a relatively shallower hard tank, and it is connected to a truss structure with a number of heave plates. The multiple heave plates greatly increase the heave added mass and viscous damping, which contributes to minimize the heave motion despite the increase of the heave wave exciting force due to shallower cylinder draft compared to conventional cylindrical spars. Recently, a series of model tests was conducted for the Amoco Marlin truss spar (see Fig.1) in the Offshore Technology Research Center's (OTRC) 3-dimensional wave basin at Texas A&M University, and the results showed that the truss spar also exhibited excellent motion characteristics.

The truss spar is in general composed of a large-volume hard tank in the upper part and slender truss members in the lower section; therefore, both wave diffraction and viscous effects are important. In the present numerical simulation, second-order diffraction theory (Kim et al., 1995) is used for the hard tank, and the Morison equation is used for the truss members and heave

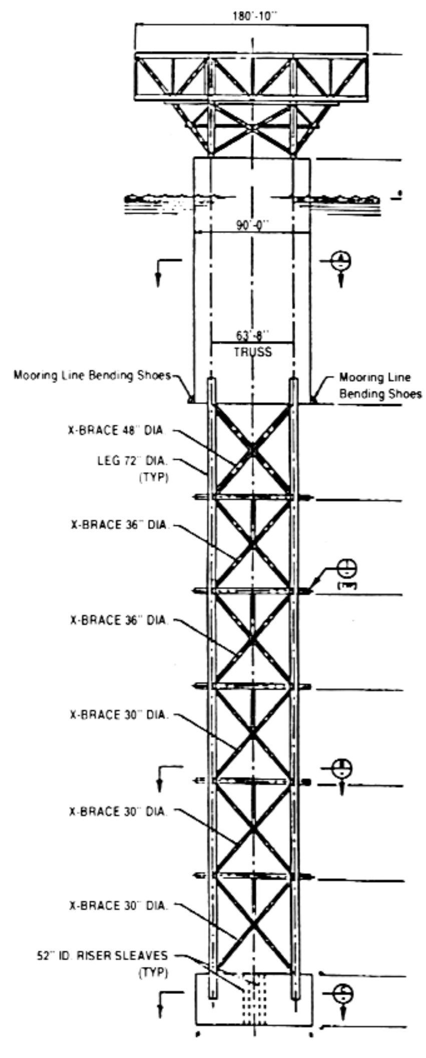

Fig. 1 Overall spar confiuration

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KEY WORDS: Truss spar, nonlinear, time domain, hull-mooring coupled analysis, mooring-line damping, second-order diffraction.