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ABSTRACT
A full time-domain analysis program is developed for the coupled dynamic analysis of offshore structures. For the hydrodynamic loads, a time domain second order method is developed. In this approach, Taylor series expansions are applied to the body surface boundary condition and the free surface boundary condition, and Stokes perturbation procedure is then used to establish corresponding boundary value problems with time-independent boundaries. A higher-order boundary element method (HOBEM) is developed to calculate the velocity potential of the resulting flow field at each time step. The free-surface boundary condition is satisfied to the second order by 4th order Adams-Bashforth-Moultn method. An artificial damping layer is adopted on the free surface to avoid the wave reflection. The mooring-line/riser/tendon dynamics are modeled by a rod theory and finite element method (FEM), with the governing equations described in a global coordinate system. In the coupled dynamic analysis, the motion equation for the hull and dynamic equations for mooring-lines/risers/tendons are solved simultaneously using Newmark method. The coupled analysis program is applied for a TLP motion response simulation. Numerical results including motions, tensions at the top of the tendons are presented, and some significant conclusions are derived.

KEY WORDS: Full time-domain; higher-order boundary element method; tendon; finite element; coupled dynamic analysis.

INTRODUCTION
Floating platforms, such as Spar, TLP, and FPSO, have been widely used for oil and gas production in deep water. With the increase of water depth, the mass and damping of mooring lines and risers become nontrivial and the surface-platform motions can be appreciably affected by them. Therefore, it is important to include dynamic interactions between surface vessels and lines. Ma et al. (2000), Lee and Flory (1999), Lee and Devlin (2000) and Kim et al. (2001a,b) showed that the conventional uncoupled or quasi-static analysis might produce unreliable results when deepwater condition is considered. In this case, an integrated approach is the coupled-dynamic analysis so that all the interactions among platforms, mooring lines/tendons, and risers, can be fully evaluated. Previous studies on the coupling effects between a moored structure and its mooring system in general followed the similar approach (de Kat and Dercksen (1994); Ran and Kim (1997); Ormberg and Larsen (1997); Ran et al. (1998); Ormberg et al., 1998). The hydrodynamic coefficients are first calculated in the frequency domain. Based on the quadratic transfer functions and an incident wave spectrum, the wave forces on the structure were then computed in the time domain, by using the inverse Fast Fourier Transform (FFT) technique and a random phase assumption. Such studies also include the drag force calculation using the Morison equation. The dynamic analysis of a mooring system was conducted in the time domain using a Finite Element Method (FEM) or lumped-mass method. The moored structure and its mooring system were coupled by matching their forces and displacements at the fairleads.

In this work, a time domain analysis based on the higher-order boundary element method is developed to compute the wave forces (Isaacson and Cheung, 1993). This method involves Taylor series expansions and the application of the Stokes perturbation procedure, and a time-integration scheme is used to obtain the resulting flow development. The mooring dynamics program is based on a global coordinate system and the rod theory (Garrett, 1982), which is expected to be more efficient than conventional FEM (Kim et al., 1994) in that various coordinate transformations involving trigonometric functions are not needed. The mooring dynamics program is coupled with the hull dynamics program in the time domain by imposing adequate boundary conditions at the intersection points. The coupled motion equations of the body and dynamic equations for mooring lines/tendons/risers are solved simultaneously at each time step using Newmark method combined with Newton-Raphson iteration scheme.

A floating Hemisphere model is first studied for validation and then the coupled analysis method is applied to the case of a TLP and tendon system. The responses of the TLP in regular waves and tensions at the top of the tendons are simulated.

MATHEMATICAL FORMULATIONS AND METHODS
Two right-handed Cartesian coordinate systems (Fig. 1) are defined in the computation. One is a space-fixed coordinate system OXYZ with its origin at the still water surface, in which X and Y are measured...