Dynamic Analysis of Tension Leg Platform Using 3D-Curved Surface Boundary Element Method

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The design of large offshore structures and their operations depend critically upon the wave-induced loads and motions. Thus, over the last two decades, substantial efforts have been devoted to the development of various principles and methods which can provide these predictions in a reliable and efficient manner. For small bodies Morison equation has been employed. It has been, however, general practice to analyze the wave force acting on large bodies on the basis of linear potential theory. The mathematical problem is solved in the frequency domain by the additional assumption of harmonic time dependence. Computer programs employing 3D-source panel method are now available for evaluating the hydrodynamic coefficients, loads and motions for structures of practical form. For large bodies with relatively simple geometry such as a vertical cylinder or sphere, these programs generally provide accurate predictions that compare well with analytical solutions and model test results. Recent surveys for the ITTC (Takagi et al., 1985) and the ISSC (Eatock Taylor and Jeffreys, 1986), however, suggested that this was not the case for more complicated structures such as a semi-submersible and tension leg platform (TLP).

Due to the inherent limit of flat panel with piecewise constant potential distribution a great number of panels are required in calculating the hydrodynamic forces with satisfactory accuracy for large offshore structures which usually have complicated underwater geometry. On the other hand, even with the ever decreasing cost of computer power, the cost for using large number of panels is still prohivitive. Lower level of discretization is therefore generally used in practice. The inadequacy of such low level of modeling, typically around 300 to 500 flat panels for a semi-submersible or

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TLP was clearly demonstrated in the study of Eatock-Taylor & Jeffreys (1986) and Jeffreys (1987). Using a hitherto inconceivably fine upper limit of over 12,000 panels, Korsmeyer et al. (1988) again demonstrated that discretization of at least 2000 facets were required for a typical TLP to give satisfactory convergence, especially for the pitch or roll damping coefficient.

In the mean time, to overcome such inherent limitation of panelmethod the higher order boundary element methods have been developed (see Tong, 1989, Liu et al., 1991, and Matsui et al, 1991) and the related numerical difficulties almost resolved. Howerver, the 1/r2 singularity problem which is inherently included in the curved element has not been completely resolved (even if resolved, rather indirectly) in the field of free-surface hydrodynamics. In this thesis, the Boundary Integral Equation (BIE) is derived in the general form from Green's third identity, and siginificant efforts have been devoted to the development of cancellation method of the 1/r2 singularity in the dipole singular kernel of the curved boundary elements. Using the method, the Cauchy type singularity problem can be resolved and so the BIE may be directly integrated without any special treatment or modification.

The TLP is a floating platform fixed by vertical legs to piled foundation templates on the seabed (see Fig.1). It is a compliant structure which allows lateral movement (sway, surge and yaw) while tether system of the tension legs restrains vertical movements (heave, pitch and roll). Buoyancy is provided by the pontoons and columns of the hull. The excessive buoyancy, greater than the platform weights, maintains the legs in tension in all loading and environmenal conditions. The response of a moored TLP to random seastate is often dominated by large amplitude longitudinal and lateral motions with frequencies significantly lower than the frequency range of the individual wave components. The motions have been known to be mainly due to the small, so-called second order, mean and low frequency wave forces. The frequencies of the second order low frequency components are associated with the frequencies of wave groups occuring in irregular waves.

The second order forces in general contain slowly varying components of which the characteristic frequency can be as low as the natural frequency of horizontal motions of the moored TLP. As a consequence, the TLP can experience an unexpectedly large horizontal excursion , which may result in a serious damage on the tether system of tension legs. In this thesis, the second order wave forces are computed on the basis of Pinkster's direct integration method in which the forces are evaluated by directly integrating pressures over the body surface (Pinkster, 1980 and Choi et al., 1990), and it will be shown that the forces can be evaluated by the presented boundary element method in so reliable and efficient manner.

A major novel part of the TLP is the mooring system, comprising the tension leg components and the mechanical handling and installation equipments. Substantial attention has been paid to the computation in the time domain of the motions and tether forces in irregular seas. In the time domain simulation of the slowly varying second order motions, nonlinearity of the TLP's tether system due to the large excursion is taken into account by modeling each tendon with a geometrically nonlinear finite cable element based on the well-known elastic catenary cable theory (Chang, et al., 1989 and Lim, et.al, 1990). The residual forces due to the nonlinear tether forces are to be quickly balanced by using the Newton-Raphson's iteration method.

In the domestic studies of TLP, Yeo, et. al.(1985) pioneered the dynamic response analysis of TLP. In their paper, among the various kinds of tension leg platforms, Deep Oil Technology (DOT) TLP was analyzed, and a numerical algorithm which would predict the dynamic response of the DOT TLP having small-diameter elongated members between large vertical columns was developed by using the previously developed numerical algorithm Floating Vessel Response Simulation (FVRS) for vertically axisymmetric bodies of revolution (Pyun, 1984). Hong, et. al. (1990) also investigated the motion characteristics of ISSC TLP using the conventional 3D-source panel method. In their study, the nonlinear effect of tethers on the motion and the Mathieu type instability were also investigated by simulation.

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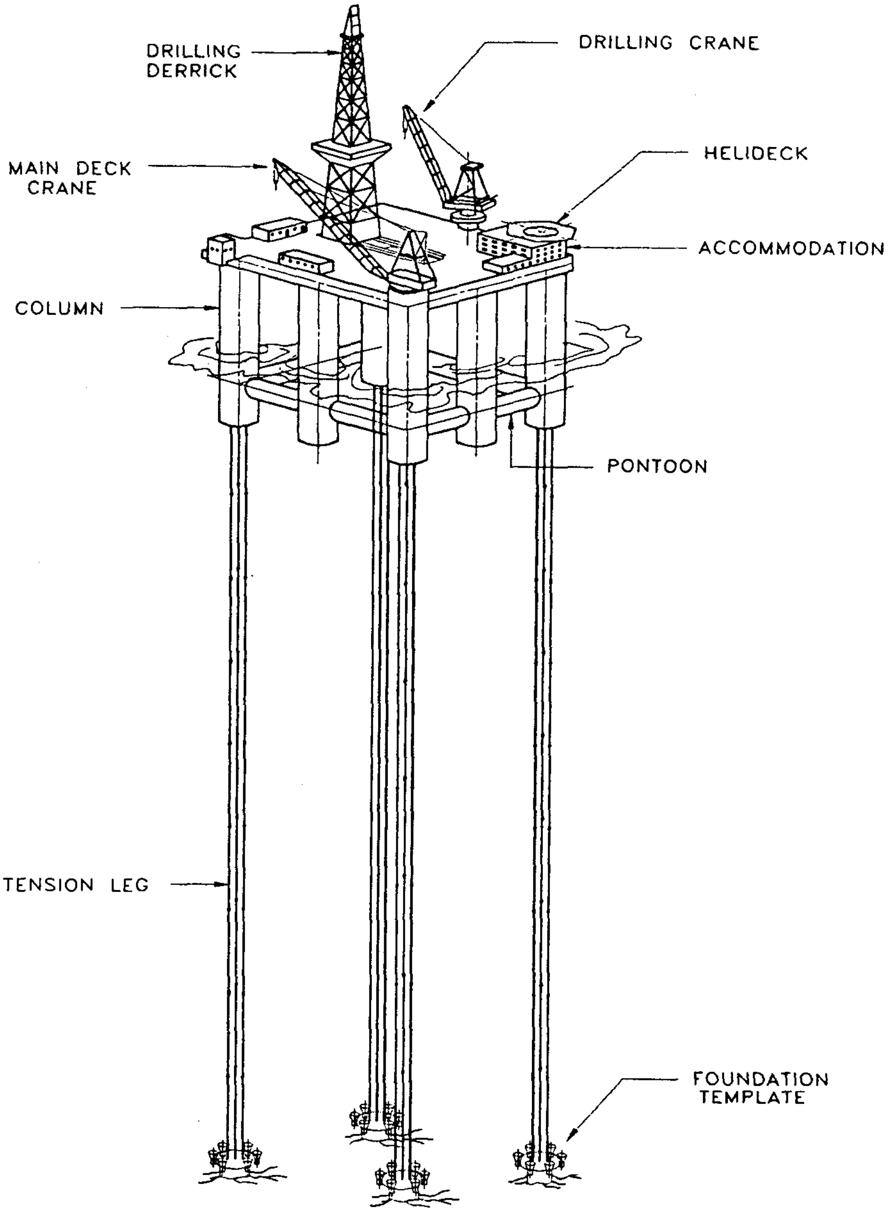

Fig. 1 Configurations of a typical TLP