Three-Dimensional Dynamics Model of Mooring Line for Coupled Motion Analysis of Floating Offshore Structure in Deep Water

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論 文 名　：　Three-Dimensional Dynamics Model of Mooring Line for Coupled Motion Analysis of Floating Offshore Structure in Deep Water
（深水域における浮体式海洋構造物の連成運動解析のための係留索の３次元動力学モデル）

区　　分　：　甲

論　文　内　容　の　要　旨

The demands of energy, especially for oil and natural gas, have increased rapidly in recent years. The rapid increase of energy demand in the future leads the gradual depletion of oil and gas resources in shallow offshore water as well as those in onshore. As consequences, oil and gas exploration is gradually moving toward deep water area where is far from the land to compensate the growing demands. The offshore development for deep water operation is indispensable to sustain oil and gas exploitation in deep water area far from the land.

Talking over the floating offshore structures used for the offshore development, one of the most important issue associated with them in recent decades is their mooring line system. Since a floating structure is connected to a flexible riser system which transports oil/gas from deep beneath of the seabed and cannot compensate the large motions of the floating structure, the mooring line system plays an important role to keep the structure in desired location and survive under severe sea condition. Due to the importance of such mooring line system, the accurate prediction of mooring line behavior including its tension and motion is compulsory and it must be considered by incorporating the dynamic effects of mooring line.

On the other hand, recently, multi-component mooring line system consisting of various types of segment lines, clump weights and/or spring buoys, has been assessed as the proper solution for deep water mooring problem and severe sea conditions. However, as the increase of water depth, the dynamic effects of multi-component mooring lines are also becoming significant and important to predict the dynamic behavior of the mooring line, and it becomes more complex due to the variation of segment line properties. These dynamic effects are often neglected in multi-component line catenary method. Hence, an adequate numerical method which can delineate the complexities of the multi-component mooring line and provide accurate results is absolutely demanded.

The aim of this study is to develop a three-dimensional dynamics model of a mooring line which is applicable for multi-component mooring line system for conducting coupled analysis of deep water floating offshore structure and mooring lines. Three-dimensional lumped mass

model for a single-component mooring line is improved by integrating interaction between the mooring line and the seabed and considering anchor force and its motion. Then, the model is extended to be applied for a multi-component mooring line taking wave, wind, and current loads and inherent characteristics of the mooring line into account. To investigate the effectiveness of the model, numerical simulations of dynamic motions are performed for both single- and multi-component mooring lines. The analysis of a moored deep water floating structure under the combination of environmental loads is also conducted.

This thesis consists of six chapters.

Chapter 1 introduces a general overview of this study including a brief review of deep water operation, offshore structure and deep water mooring line system. A literature review is presented associated with mooring line dynamics, multi-component mooring line, and mooring line analysis approach. The objectives and expected outcome of this research as well as a brief layout of this thesis are also presented.

Chapter 2 describes numerical model used for introducing simultaneous motion between a ship-type floating offshore structure and mooring line considering wave, wind, and current loads. In this chapter the method used for obtaining wave forces is described and the hydrodynamic coefficients used in simultaneous motion equations combining mathematical manoeuvring model based on the Manoeuvring Modeling Group (MMG) and conventional floating body motion equations are presented.

A three-dimensional dynamics model for calculating mooring line is presented in Chapter 3 involving line-seabed interaction and dragging anchor motion. The governing equation of three-dimensional dynamics model for mooring line and its solution are explained in this chapter. Numerical simulations associated with the coupling of this mooring line model and a ship-type structure are carried out. The simulations involve single point, double line, and multi-leg mooring systems including turret and spread mooring which are performed under various environmental conditions for each system.

Furthermore, to outcome the problem of multi-component mooring line dynamics, three-dimensional dynamics model of a multi-component mooring line is developed and presented in Chapter 4. The verification of the developed model either for the mooring line itself and its coupling with a ship-type structure are provided. Comparisons against two-dimensional model results are also presented.

Moreover, to verify the developed multi-component mooring line dynamics model to be applied in realistic operation, the coupling of the developed model with a ship-type structure under realistic operation is simulated and reported in Chapter 5. The characteristics of mooring line, mooring line configuration, and environmental data are considered based on measured metocean data. The various cases including collinear/non-collinear and in-line/in-between line conditions are accounted to the simulations.

Finally, the conclusion of this research and recommendation for future work are drawn in Chapter 6.