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Eigenvalue Analysis for Motion Response of a TLP and Tender Semi Considering a Complex Mooring Configuration

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Eigenvalue analysis was carried out for a complex system of multiple floating bodies with various connectors. In this study, multiple floating bodies are a tension leg platform (TLP) and a semisubmersible platform that are connected with hawser and mooring lines. To perform the eigenvalue analysis, mathematical formulation is derived including linear stiffness and added mass matrices. A systematic approach is adopted for the derivation of the linear stiffness matrix by considering both pretension and spring effects, which can be applied to general floating body system with complex moorings. First, a single floating body system of the TLP is investigated to validate the present eigenvalue analysis method. Discussion is made on the effect of mooring pretension or axial stiffness on the natural period of the floating body. Then, a multiple floating body system including the TLP and tender semi is considered. In this case, the analysis results are validated by comparison with the experimental data.

INTRODUCTION

In various offshore applications, a multiply connected floating body system is a frequent occurrence. In many cases, multiple floating bodies are located in close proximity and connected with a complex mooring system including catenary mooring, tether, and hawser lines and various interface units. In this case, not only hydrodynamic interactions but also mechanical interactions become significant for motion responses of the multiple floating body system. To design these complex systems, careful attention should be paid to the motion characteristics of the total system including coupled motion responses. For this purpose, a time-domain simulation or model test can be applied to these problems to evaluate the performance of those operations directly. In addition to that, a frequency-domain analysis and eigenvalue analysis can be introduced to investigate the whole-system characteristics including natural periods and mode shapes.

Regarding the multiple floating body problem, various previous studies have been conducted experimentally and numerically. A typical example of this problem is a side-by-side or tandem operation between an offshore production platform and a shuttle tanker (or carrier). For example, Buchner et al. (2001) conducted model tests on a floating production storage and offloading (FPSO) unit and a shuttle tanker in a side-by-side configuration. Hong et al. (2002) also carried out a series of model tests on a liquefied natural gas (LNG) FPSO and a shuttle tanker in various configurations, such as single, side-by-side, and tandem configurations. They also numerically applied a higher-order boundary element method (HOBEM) to solve the multiple floating body problems in the frequency domain, focusing on the coupled effect of the motion response of the vessels and the repulsive wave drift forces. The three-body problem of the FPSO, LNG carrier, and shuttle tanker was also investigated in model test by Hong et al. (2005). They discussed the characteristics of wave-induced motion response and wave drift force in three-body problems. Recently, Cho et al. (2011) performed model tests on the side-by-side two-body problem including a sloshing effect. Using time-domain simulation methods, Ye et al. (2005) and Koo and Kim (2005) presented mooring analysis results of an FPSO unit and a shuttle tanker. Park et al. (2013) used a numerical method to investigate the side-by-side problem and particularly used computational fluid dynamics to examine the sloshing effect.

The connection of a tender vessel to a tension leg platform (TLP) is another example of a multiple floating body problem. In this case, the verification on the coupled system under various environmental conditions should be considered to ensure the safety of the tender vessel system and hawser lines. There are a few studies on the TLP with a tender supported vessel. Korloo et al. (2004) showed a comprehensive analysis on the TLP with a tender semisubmersible for the West Seno field. Xia and Taghipour (2012) conducted a feasibility study on the TLP with a tender-assisted drilling project, showing the eigenvalue analysis for mooring designs. However, their analysis was restricted to the longitudinal motions of two bodies only. Choi et al. (2018) showed an experimental and numerical analysis to investigate the coupled behavior of a TLP combined with a tender semisubmersible platform. They introduced an eigenvalue analysis to check the natural modes and periods of the multibody system while focusing on the horizontal motion modes.

In this study, eigenvalue analysis was carried out for a complex system of a TLP and a tender semisubmersible platform in close proximity, where the multiple floating bodies are connected with various hawser and mooring lines. First of all, mathematical formulations are derived for the eigenvalue problem of a multiple floating body system with full degree-of-freedom motion modes considered. In particular, a systematic approach is explained for

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