Prediction on Course Stability of Towed Offshore Structures by Computational Fluid Dynamics

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ABSTRACT

The purpose of this research is to find the practical methods to predict the course stability of towed offshore structures in the early design stage. The equilibrium yaw angles of the towed FPSOs with single skeg and twin skegs are predicted by CFD analysis and towing simulations using CFD are performed. The prediction results are compared with the towing model test results. Furthermore, the mechanism of instability is analyzed through investigation of the physical quantities from CFD.

KEY WORDS: Towing; course stability; prediction; CFD, equilibrium; simulation; hydrodynamic derivative.

INTRODUCTION

Currently, there is an increase in demand for very large offshore structures such as FPSOs, semi-submersibles, as deep-sea resource development technology has been advanced. Accordingly, the number of projects of towage from shipyard where the offshore structures are constructed to oil development field is increasing as well. If the course stability is not secured enough during towing, damage on the offshore structures from collision or catastrophic pollution on the marine environment from oil spill may occur. Consequently, the prediction on the course stability of towed vessels is one of the most important parts of the offshore structure development project.

The evaluation and prediction methods are divided into four categories as applying the stability criteria, performing the towing test, numerical analysis and recent CFD(Computational Fluid Dynamics) analysis. Stranghagen et al (1950) investigated the course stability criteria for towed vessels using Routh-Hurwitz stability criterion. Berteas and Kekerdis (1985) suggested the discriminant using characteristic equations derived from equations of motion of a towed vessel.

As of now, the prediction on the course stability of towed vessels in the design stage heavily depends on the model tests. Latore (1988) investigated the scale effect on the course stability of towed barges. He found that the model resistance is larger than the full scale resistance and indicated that the model barge may overestimate the course stability compared to the full scale barge due to the scale effect. You (2000) carried out towing model tests for a tanker ship and a FPSO and found out that the FPSO has higher course stability than the tanker. Jung et al (2005) performed towing model tests to investigate the bow shape effect on the course stability of FPSOs. Two different types of bow shapes were tested: one of a barge shape and another of a spoon bow shape. It is found that bow of barge shape has higher course stability than bow of the spoon bow shape. Yang et al (2006) extensively carried out the towing model tests for the different stern hull shapes, skegs and bilge radii of a FPSO. Kwon et al (2007) performed the towing model tests for the forward blocks of container and tanker vessels. As the forward blocks of the container ships were more slender than those of tanker ships, the towing model tests resulted that the container blocks were towed with fish-tailing motion. Yang et al (2011) carried out a comparative towing test of course stability of two cases: one that a FPSO is directly towed by a towing carriage and another that a FPSO is towed by a free-sailing tug model. This test was to investigate how the interactions among tug, towing line, and towed structure influence the course stability.

Although the model test is highly reliable, there is some level of limitations in time, cost, measurements and test facilities. Therefore, it is difficult to predict and optimize the performance and analysis of instability mechanism using the model test. In addition to the model test, a number of numerical approaches have been studied. Yasukawa et al (2006) carried out a numerical towing simulation with a 2D lumped mass model to express the dynamics of the towing line. The captive model tests were carried out to capture the hydrodynamic coefficients of barges. The simulation results were compared with the towing model test results. Nam et al (2012) performed the numerical towing simulations using MMG(Mathematical Manoeuvring model Group) and Cross-flow model and compared the results to the model test results. Fitriadhy, Yasukawa and Koh (2013) investigated the wind load effect on the course stability of a ship towing system using numerical analysis.

However, there are limitations on numerical approaches because the hydrodynamic characteristics of vessels must be known. The empirical or regression formulas can be applied to predict the hydrodynamic characteristics, only applicable within the database and changes of partial configuration cannot be considered. Especially, it is difficult to