論文の内容の要旨

論文題目　Prediction of dynamic response of floating offshore wind turbine using updated hydrodynamic models

（精緻化した水力モデルを用いた浮体式洋上風車の動的応答予測）

氏　　名　張　士寧

Shining Zhang

Floating Offshore Wind Turbine (FOWT) is an innovative prospective and attractive technology in the development of offshore wind in deep water. Dynamic responses of semi-submersible platform supported foundation have been extensively studied. The simple construction onshore and the low draft making it applicable for different water depths render the semi-submersible platform a promising design option. In recent years, intense R&D effort has been spent in making several prototype FOWTs into reality, such as WindFloat and three semi-submersible FOWTs in Fukushima FORWARD project. Accurate prediction of dynamic response of FOWT by design tools is a matter of great importance for the safety concern. Considering the cost of the structure, slender members are commonly used in the semi-submersible platform, which makes a Morison's equation applicable for evaluation of hydrodynamic loads. But, the differences between predicted responses by the Morison's equation and measurements indicate that the conventional Morison's equation needs to be improved. In addition, the effects of wave spreading and nonlinearity of wave on dynamic responses of FOWT are not fully clarified in previous studies. Finally, heave plates are widely used in the semi-submersible platform to mitigate the response, and determination of hydrodynamic coefficients for the heave plates is important for the calculation of responses. Formulas to determine those hydrodynamic coefficients are preferred for optimized designs of structures with heave plates.

In present study, three scaled models in water tanks are conducted to validate the developed simulation tool, CAsT, a fully coupled nonlinear time domain motion analysis software. Present study focuses mainly on the validation of improved hydrodynamic models of the semi-submersible FOWT by experimental model testing. Aerodynamic loads from wind are assumed to be non-existent. Only wave-induced response and mooring-line induced nonlinearities are considered as the targets in present study. Morison's equation is used to evaluate hydrodynamic loads on the platform and mooring lines. The improved hydrodynamic models, wave models, and hydrodynamic characteristics of multi-plates are numerically studied and validated against the water tank tests.

In Chapter 1, the general background of this study, review of development of floating offshore wind turbine, comparison of types of FOWT, literature review in terms of modelling of FOWT, and outline of this thesis are presented.

In Chapter 2, three water tank tests are described. One is used to evaluate the hydrodynamic coefficients of the scaled 2MW FOWT platform model by forced oscillation tests in horizontal and vertical direction. The other is used to evaluate the hydrodynamic characteristics of a spar with multi-plates. The third one is used to measure the dynamic response of a semi-submersible FOWT in regular and irregular waves. The measured dynamic response of the FOWT in various marine conditions are used to validate the performance of proposed hydrodynamic models in this study.

In Chapter 3, the performance of updated hydrodynamic models in prediction of dynamic response of floating offshore wind turbine to sea states is validated by water tank test. Three issues related to hydrodynamic models are discussed in this study. Firstly, effects of unsteady characteristics of hydrodynamic coefficients are investigated by a free decay test. Then, the axial Froude-Krylov force on slender members is included in conventional Morison's equation and is clarified by the water tank tests with regular and irregular waves. Finally, dynamic behavior of mooring system on fairlead tension is investigated by using quasi-static and dynamic model respectively. With the improved hydrodynamic models, the dynamic response of a semi-submersible FOWT from the full coupling analysis shows a good agreement with measured water tank experimental response.

In Chapter 4, the effects of multi-directional wave and nonlinear irregular wave models are investigated with a prototype FOWT. It is found that multi-directional wave, compared with unidirectional wave, decreases the maximum of motion in surge, heave and pitch direction. It is suggested that the employment of multidirectional wave is beneficial for cost-effective platform design of FOWT in deep water. As with nonlinear irregular wave, one constrained wave model is employed to achieve one extreme wave height required in extreme deterministic design. Consequently, it is found that nonlinearity of irregular wave plays an important role in the shallow water, while in the deep water, nonlinearity of irregular wave could be ignored.

In Chapter 5, hydrodynamic coefficients, namely added mass coefficient (C_a) and drag coefficient (C_d), for a spar with multi-plates are numerically predicted by Large Eddy Simulation model. Formulas of C_a and C_d for various types of heave plates are proposed. Predicted hydrodynamic coefficients by present numerical simulation and proposed formulas are validated by the results obtained from water tank tests and literature. Moreover, interaction between the multi-plates and mechanism of the hydrodynamic characteristics are clarified by numerically computed flow fields. Finally, the proposed formulas are used to conduct optimized designs of multi-plates.

Chapter 6 summarizes the conclusions of this study.