A Coupled Approach for Dynamic Modelling of a Semi-submersible Type Platform with Multiple Diffuser-Augmented Wind Turbines

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論文題目：　A Coupled Approach for Dynamic Modelling of a Semi-submersible Type Platform with Multiple Diffuser-Augmented Wind Turbines
（複数ディフューザー風車を搭載したセミサブ浮体に関する連成解析モデルの開発）

区　　分：　甲

論　文　内　容　の　要　旨

Rapid growth of the human demanding for the energy resources raises an urgent issue to the nations worldwide today for seeking safe, clean and renewable energies in the form of other than the pollution-carrying and exhaustible conventional fossil fuels or nuclear powers. As one of the latest technologies, the offshore wind industry is seeing a significant increase in activity in the present and the near future. Due to the limitation of fixed offshore turbines locating at shallow continental shelf while most of the wind resources exist further offshore, market transition to deeper waters is inevitable, provided that suitable technologies could be developed. Because of the presence of comprehensive loading involving the wave-induced forcing, the wind-induced forcing and the mooring restoring forcing, dynamic behavior of the floating offshore wind turbine becomes extremely complicated in nature. Furthermore, new challenges are imparted by the coupling between the support platform motions and the turbine motions.

The present thesis concentrates on the feasibility study of the semi-submersible type platform mounted by multiple diffuser-augmented wind turbines, which is under development in Kyushu University. In relation to other floating concepts, it is lower in pitch and roll motions as well as economic cost, attributed to the lots of slender trussed members that have been used for connections between the major columns. In this situation, the viscous drag force increases to an equivalent magnitude with the inertia force which generally takes an overwhelming role in the offshore oil rigs who have large columns. The standard panel method, associated with the Morison stick method, have been developed and combined together to form a special hybrid model to account for that characterization. Different hybrid styles have been studied and compared, leading to a conclusion that neglecting the inertia part while meanwhile keeping the drag part of the wave-induced forces will help finding the solution as efficient as even an analytical model without loss of too much accuracy. Comparison between the hydrodynamic computations performed in infinite depth and in the designed finite depth shows that the effect of finite depth is not as remarkable as preconceived. The diffuser with a special name of “WindLens”, which shrouds on the normal turbine, would augment the inlet flow in the stream tube that goes through the rotor plane. To account for this, the generalized actual disc theory proposed by Jamieson for modeling the ducted rotor has been further extended to include appropriate Glauert corrections in the turbulent wake state, with its performance being evaluated by

the effective diffuser efficiency. This one dimensional theory has been later developed into a generalized version of the blade element method code. As an important parameter, the diffuser axial induction, can be predicted by establishing an effective empirical model which is also used for prediction of the axial velocity profile at the rotor plane bearing various thrust loadings. Moreover, unlike other floating offshore wind turbines, the presence of multiple wind turbines gives rise to the wake loss effect for the downstream wind turbines on the semisubmersible platform, or the mutual interactions between each other in the floating wind farms. The Jensen’s (Park) model has been therefore selected to count the speed deficit in the wake behind an upstream turbine. To maintain the stability of the floating system, mooring system is necessary for providing the restraint. It has been modeled by an improved catenary theory proposed by Jonkman which can further consider the friction from the seabed for the resting part of the mooring lines. All the above external forces have been finally put together to form integrated motion equations in the time domain, whose convolution kernels are calculated from the output of the frequency domain preprocessor that has been developed in this work. Coupling effects between the platform motions and the turbine motions, which significantly change the freestream wind inflow velocity, have also been considered through an analysis of the relative motions. Several application computations have been carried out for studying the performance of the prescribed floating offshore wind turbine system under various environmental conditions. Results show that the diffuser augmentation enhances the power output of the wind turbines and increases the induced thrust loading, the existence of wake loss effect reduces the efficiency of the downstream wind turbines and influences the yaw motion of the floating system thus cannot be ignored, and the integrated floating system is feasible in the given environmental conditions.

In the chapters to follow, we firstly outline the panel method that has been developed in this work for calculation of the hydrodynamic loads on the floating platform. In chapter 3, a new algorithm for numerical solution of the finite depth free-surface Green function is presented, which is used to study the finite water depth effect on the platform. In chapter 4, we described the methodology of Morison-type model, which is further combined with the panel method to study the viscous effect of waves upon the platform. In chapter 5, the Jamieson’s aerodynamic theory for ducted wind turbines is further developed and used for the blade element computation. In chapter 6, the dynamics of mooring system is considered by an improved catenary theory, and a time-domain solver is developed for integrated analysis of the floating wind turbine system, which uses the output from the frequency-domain preprocessor. The numerical simulation tool is finally used to predict the floating wind turbine dynamics for the purpose of economic assessment and optimization design.