

Numerical Simulation of a TLP in Large Waves by OpenFOAM

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1. Background and Objective

The development of offshore renewable energy has become especially important in today's era when development of onshore renewable energy is approaching its limits. As a clean and renewable resource, offshore wind energy has attracted more and more attention. Offshore wind turbines are developed to harvest such offshore wind energy resources. With the development of wind energy to deep water, research and development of floating foundations for the wind turbines is required.

Floating wind turbines need to maintain operation in specific sea areas for a long time, so mooring systems are required to restrain the movement of the system caused by external loads. Especially, the floating foundation is not allowed to have a large motion response to waves, in order to ensure a stable power output of the wind turbine as well as to satisfy the safety requirement. Since the real marine environmental conditions for the floating wind turbine system are very complex, it is necessary to study the motion response characteristics of the floating wind turbine under different sea conditions, in order to design a floating wind turbine system which satisfies, the safety requirement, and the requirement wind turbine operation.

The purpose of this research is to use OpenFOAM, an open source CFD software, to study the safety issue of a new type tension leg platform (TLP) under extreme wave conditions.

2. Research Subject and Method

In this research, a TLP system which can be used for offshore wind turbine or offshore met mast, as shown in Fig.1, is selected as the target. Numerical simulation on the floating body is carried out by using OpenFOAM under

extreme sea conditions.

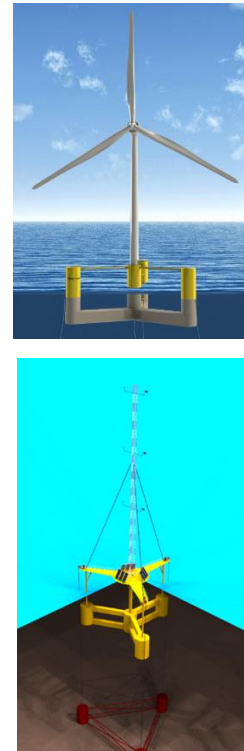


Fig.1 Examples of TLP for offshore wind purpose

The extreme wave condition used in the simulation is that the water depth is 100m, the wave period is 15.8sec, the wavelength is 365.3m, and the wave height is 10m. Tendon length is set to 88m. The computational domain is 800m long, 40m wide, and 90m high. The computation mesh, as shown in Fig.2, is generated by OpenFOAM, with the total cell number of about 7 million.

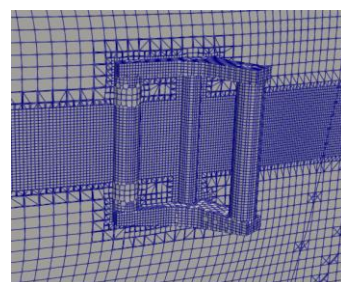


Fig.2 Computation mesh

The time-history characteristics and energy spectrum characteristics of the wave loads on the platform, as well as the tension force of the mooring line are obtained by the CFD simulation. The CFD results are compared with the results calculated by a potential flow theory method.

3. Simulation Results and Analysis

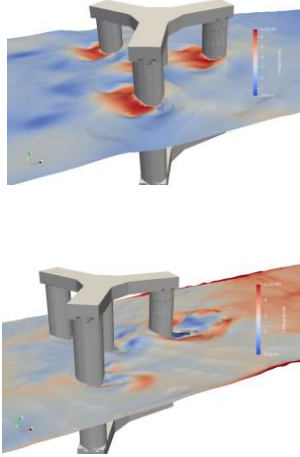


Fig.3 Free surface profiles obtained by the CFD simulation

In Fig.3, CFD simulation results on regular waves interacted with the platform are shown. The free surface profile becomes very complex and the overall wave front is greatly affected by the columns of the platform. The flow shows full three-dimensional characteristics. It can be seen that due to the existing of the floating body local secondary waves appear, which are caused by the radiation wave and diffraction.

Figure.4 shows a comparison between the CFD simulation and the potential flow theory simulation. The CFD simulation can reproduce more sophisticated phenomena than the partial potential flow theory calculation. That means CFD method can capture the high-order components of the wave and display a more realistic flow field variation. Under extreme sea conditions, the nonlinear phenomena on the wave radiation and diffraction are more significant. For pitch motion, more significant nonlinear phenomena can be seen when compared with the surge motion and heave motion.

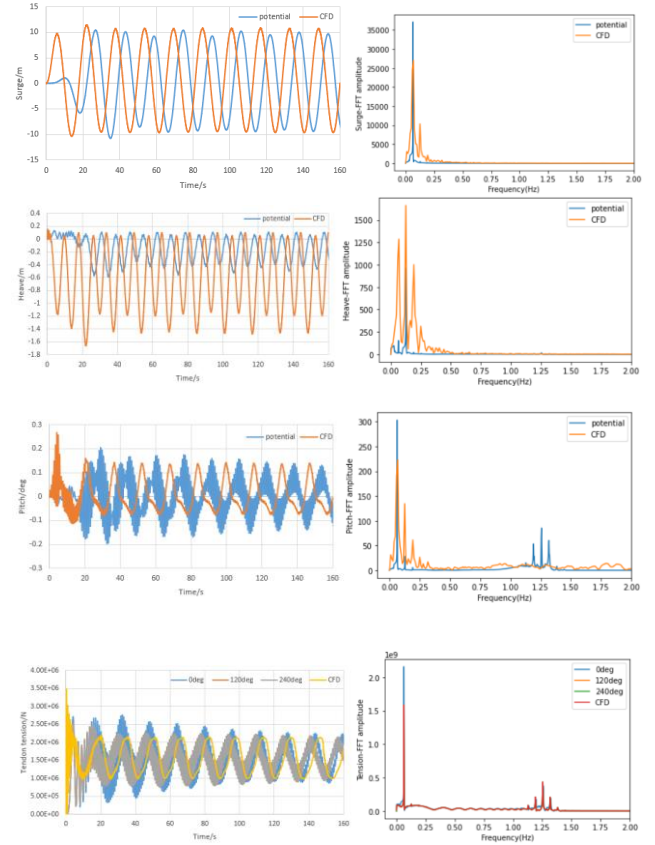


Fig.4 Comparison between CFD result and potential flow theory result

4. Conclusion and Future work

CFD simulations by OpenFOAM have been carried out to study the motion characteristics of a TLP. First, the CFD simulation on a well-documented benchmark case, a floating block in regular waves is carried out, and it is found that the present results agree well to those in the literature, which verify the accuracy and reliability of the CFD method. Then the motion response of the TLP under extreme sea conditions are studied by CFD simulations. The time-history characteristics and energy spectrum characteristics of the platform motion and the force of the mooring system are investigated. The CFD results are also compared with the results obtained by a potential flow theory. For future work, it is suggested to perform CFD simulation on larger wave heights, such as twenty meters, to study the effect of further extreme sea conditions.