Aerodynamic Simulation of the Marintek Braceless Semisubmersible Wave Tank Tests

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Introduction

Model scale experiments of offshore floating wind turbines are important for both platform design for the industry as well as numerical model validation for the research community. An important consideration in the wave tank testing of offshore wind turbines are scaling effects, especially the tension between accurate scaling of both hydrodynamic and aerodynamic forces. The recent Marintek braceless semisubmersible wave tank experiment utilizes a novel aerodynamic force actuator to decouple the scaling of the aerodynamic forces (see Figure 1). This actuator consists of an array of motors that pull on cables to provide aerodynamic forces that are calculated by a blade-element momentum code in real time as the experiment is conducted. This type of system has the advantage of supplying realistically scaled aerodynamic forces that include dynamic forces from platform motion, but does not provide the insights into the accuracy of the aerodynamic models that an actual model-scale rotor could provide.

Figure 1: MARINTEK Braceless Semi-submersible Experiment

The modeling of this system presents an interesting challenge, as there are two ways to simulate the aerodynamics; either by using the turbulent wind fields as inputs to the aerodynamic model of the design code, or by surpassing the aerodynamic model and using the forces applied to the experimental turbine as direct inputs to the simulation. The latter approach could lead to modeling instabilities if the hydrodynamic modeling is inaccurate, as the platform motion induced aerodynamic forces would be decoupled from the simulated motion of the platform. This paper will present a comparison of the data from these experiments with a FAST model of the platform. Free-decay, regular wave, and irregular wave tests will be presented, with and without wind inputs. In particular, the best practices of modeling this type of novel aerodynamic actuator will be discussed.

Approach

As the data has not been released at the writing of this abstract, simulation will be used to replicate the experiment and actuator for this preliminary work. The National Renewable Energy Laboratory's wind turbine design software FAST will be used with the spar buoy model from the Offshore Code Comparison Collaboration project (OC3) [1]. For the final paper, a model of the MARINTEK experiment will be used as well. To replicate the novel aerodynamic actuator used in the experiment, an addition to the FAST software had to be written that allows the aerodynamics calculation to be bypassed. In this way, a reference simulation could be run with the standard version of FAST, and the aerodynamics loads from this baseline simulation could be applied to a second simulation. To model the uncertainty in the platform modeling of an experiment, the hydrodynamic drag coefficient was modified. A series of simulations are then run, using identical wind and wave inputs, but bypassing the aerodynamic calculation for one set of simulations.

Main Body of Abstract

In this section, preliminary results from the simulation-only study will be discussed. The wind and wave inputs used here can be seen in Table 1. These significant wave height and peak spectral period values were taken from a study of the NOAA floating data buoys, and correspond to the expected value for the specified wind speed at a representative site from the east coast of the United States [2].

Table 1: Wave Parameters used in the simulations

Mean Wind Speed (m/s)	4	6	8	10	12	14	16	18	20	22	24
Significant Wave Height (m)	1.1	1.2	1.3	1.5	1.8	2.2	2.6	3.1	3.6	4.0	4.5
Peak Spectral Period (s)	8.5	8.3	8.0	7.7	7.4	7.5	7.6	8.0	8.5	9.0	9.4

A baseline simulation of the OC3 spar buoy was run for each of these wind speeds, using the corresponding wave parameters. Next, these 11 simulations were repeated with the same wind and wave inputs (keeping the random seeds, and thus the turbulence and random waves the same), but with the platform hydrodynamic drag reduced from 0.6 to 0.5. Figure 2 shows a plot of the standard deviation of the surge motion of the platform for each drag coefficient and each wind speed.

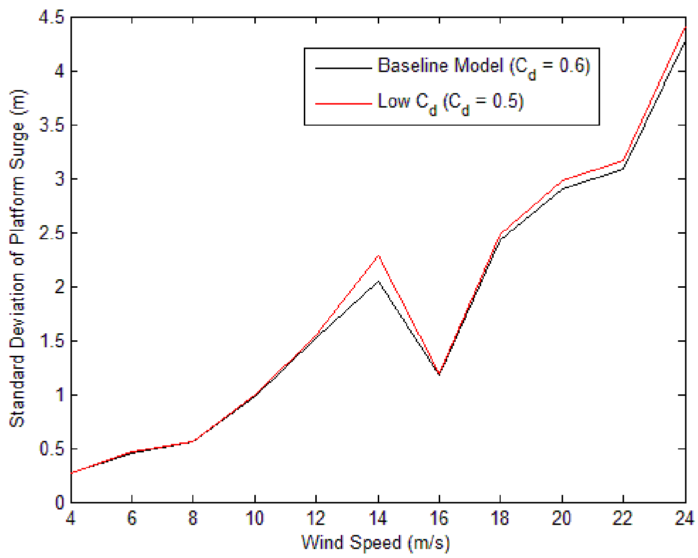

Figure 2: Impact of Cd on platform surge variation

It can be seen from Figure 2 that the difference in the standard deviation of surge is small when just the coefficient of drag is changed. To represent what will happen when using the rotor force inputs from the experiment, the force and moment time series at the rotor hub from the baseline model were saved in a separate file and used to represent the reported forces from the experiment. Since these forces include effects from platform motion (including aerodynamic damping), they are only valid when the platform is moving exactly as the simulation that they came from. If these forces and moments are used for a simulation with reduced Cd (representing modeling error), the plot in Figure 3 can be found.

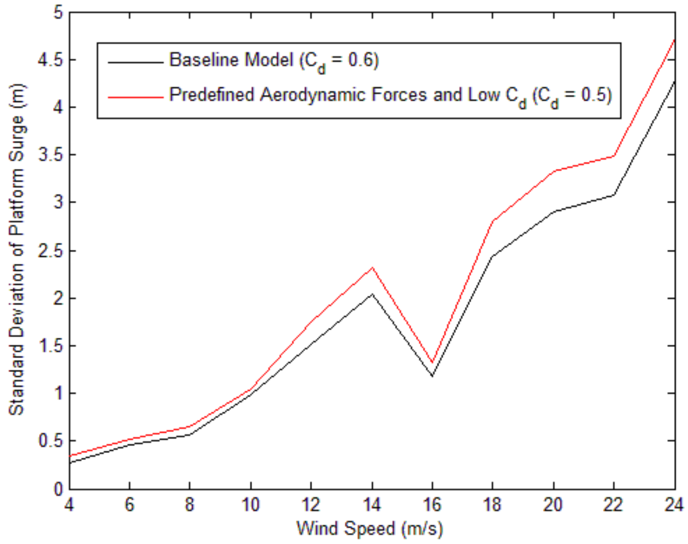

Figure 3: Comparison of baseline simulation and low Cd simulation using predefined aerodynamic forces and moments

Here, the difference between the surge variation is much larger, with a difference over 10% for some wind speeds. This is due to the platform drag coefficient changing the platform motion enough to uncouple the phasing between the platform motion and the resulting aerodynamic damping force, which in this simulation is not dependent on the actual motion. Note that these simulations have exactly the same wind and wave inputs, which would not be possible to do when modeling a real experiment, creating further discrepancies.

Conclusions

While these novel aerodynamics actuators create an opportunity to eliminate the Reynolds mismatch between hydrodynamic and aerodynamic loads at model scale, they do present some modeling difficulties. Using the aerodynamic force time-series directly from the experiment in the simulation will cause problems due to the uncoupling of the platform motion and the aerodynamic forces. A better approach may be to use the full-field wind input from the experiment, and let the coupled aerodynamics solver of the simulation tool being used. The downside of this approach is that it may introduce more errors with aerodynamic solvers other than the one used for the experiment. The full paper/presentation will investigate these methods using both purely simulation approaches like the one used in this abstract and part of the data from the MARINTEK experiments.

Learning Objectives

- **Present brand new experimental data from a floating platform that uses a novel aerodynamic actuator**
- **Create and validate a simulation model of this experiment**
- **Investigate best practices for the modeling of this type of actuator using simulation tools and the experimental data**

References

1. Jonkman, J. M. (2010). Definition of the Floating System for Phase IV of OC3. National Renewable Energy Laboratory.
2. Stewart, G. M., Robertson, A., Jonkman, J., and Lackner, M. A. (2016) The creation of a comprehensive metocean data set for offshore wind turbine simulations. Wind Energ., 19: 1151–1159. doi: 10.1002/we.1881.