Numerical modelling and validation of a semisubmersible floating offshore wind turbine under wind and wave misalignment

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1. Introduction

Coupled aero-hydro-servo-elastic simulation tools play important role in the design of offshore floating wind turbines. For rational design of the system, accuracy of the numerical tool is important in predicting the system responses. While the load cases where the wind and wave are aligned are sometimes the largest contributor to the design, evaluation of the load cases where the wind and wave are in misaligned condition are also required in the design codes. In this study, first a series of water tank test is performed for a 1/50 scale semisubmersible floater and results for irregular wave tests with aligned and misaligned wind were analyzed. Then, an in-house numerical tool, NK-UTWind is used to model the full scale system, and results for aligned and misaligned cases are validated.

2. Water tank test

The water tank test were conducted using a 1/50 scale semisubmersible floater with 2MW wind turbine at Ocean Engineering Basin of National Maritime Research Institute, Japan, in July 2011. To simplify the effect from the moorings, tout mooring was chosen for the system.

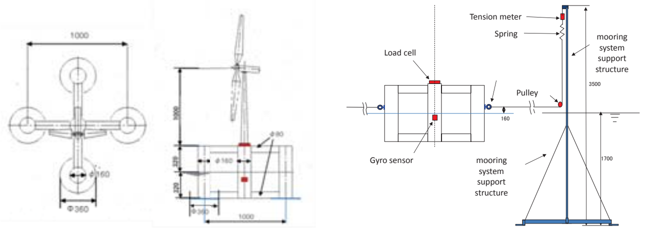

Figure. Outline of the scale model (Left) and the mooring system (Right)

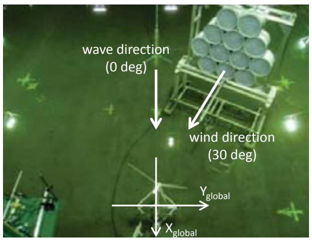

Figure. Picture of main shaft measurement

Results for irregular waves with the wind turbines in steady rotation are used for the validation. The wave conditions, wind conditions and wind turbine rotational conditions are the same for the two cases, except the direction of the wind and the nacelle yaw are set in 30 degree misalignment to the wave direction for the misaligned case.

Table. Test conditions for the validation

Wave condition	Wind condition	RPM	Duration	Blade pitch
JONSWAP, $\gamma = 3.3$ Hs=6 m, Ts=13.01s	U=13.05m/s, Iu=5.9%	22.0	6120 sec	2.4 deg

3. Numerical modelling

NK-UTWind is an in-house code of coupled analysis for floating offshore wind turbine developed by ClassNK and University of Tokyo. The code solves the equation of motion for wind turbine support structure modelled with FEM beams. The hydrodynamics for the platform is evaluated with Morison equation, and the forces from the wind turbine calculated with FAST are passed to NK-UTWind as tower top loads. The mooring lines are modeled using linear spring in this study.

The added mass coefficient Cm and the drag coefficient Cd in Morison equation as well as the Rayleigh damping term were calibrated using the free decay tests. Most of the calibrated coefficients were in the range of theoretical values for cylinders. Rayleigh damping was obtained as 2.5% from the results of linear damping coefficients.

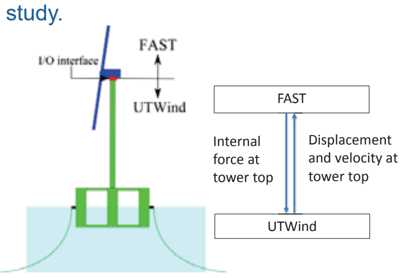

Figure. Outline of the coupling of NK-UTWind and FAST

Table. Calibrated added mass and drag coefficients

	Centre Column (X, Y)	Centre Column (Z)	Side Column (X, Y)	Side Column (Z)	Horizontal Brace (X, Y)
C_m	0.9	1.0	0.75	0.57	0.9
C_D	1.0	5.0	1.0	6.0	1.0

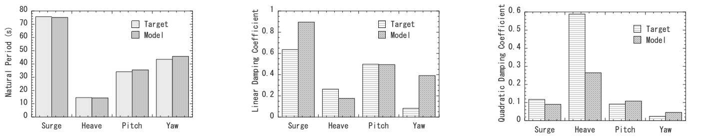

Figure. Comparison of calculated and measured natural period (left), linear damping coefficient (middle) and quadratic damping coefficient (right)

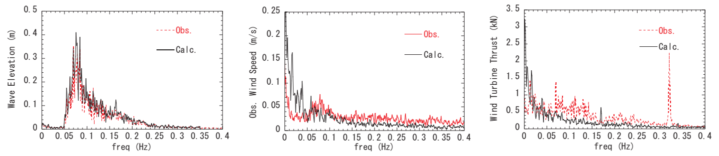

Figure. Comparison of calculated and measured amplitude spectra of wave (left), wind (middle), and wind turbine thrust force (left)

4. Results

Comparison of the calculated and measured floater motions for aligned and misaligned wind and wave conditions are shown in the figures below. Measured motions in surge, heave, and pitch are similar for the aligned and misaligned cases, while sway and roll motion were dominated by components in the natural frequency for the aligned case, while the wave frequencies are also excited for the misaligned case. Calculations agreed well with the measurement for the roll motion, while several peaks were not captured by the calculation for the sway motion.

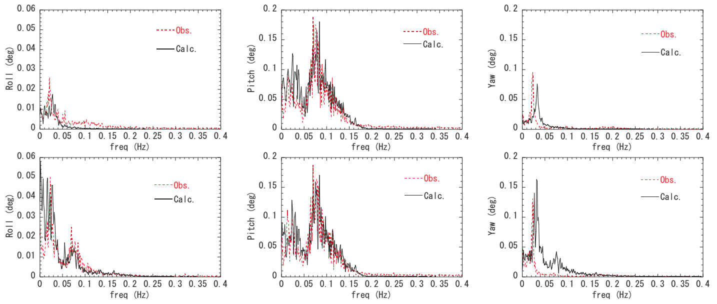

Figure. Amplitude spectra of the floater rotational motion for the aligned case (Upper Row) and the misaligned case (Lower Row)

The characteristics of frequency distribution of measured tower-base My were similar for both aligned and misaligned cases. Measured tower-base Mx showed that while the roll natural frequency component was dominant in the aligned case, the wave frequencies are also excited in misaligned case

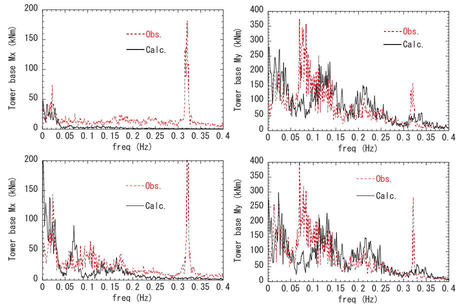

Figure. Amplitude spectra of tower base loads for the aligned case (Upper Row) and the misaligned case (Lower Row)

5. Conclusion

Measured surge, heave, and pitch motions and tower-base Fx and My loads are similar for the aligned and misaligned cases, and were well reproduced by the calculation. Measured sway and roll motion and tower-base Fy and Mx loads were dominated by components in natural frequency for the aligned case, while the components in wave frequencies increases for the misaligned case. Calculation agreed with the measurement for roll motion, while other responses needed further investigation.