The 2018 Structures Congress (Structures18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Evaluation of the effect of hurricane induced swell on the global response of floating offshore wind turbine

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ABSTRACT

This paper presents the results of a simulation-based study aimed at evaluating the response of floating offshore wind structures in offshore environmental conditions during hurricanes. The marine environment data used in the study was obtained through simulation of hurricane scenarios using the University of Miami Coupled Model (UMCM), one of the hurricane numerical prediction models. We analyzed the response characteristics of the swell component of the wave spectrum to the floating offshore structure through the used load. We used wave age criterion to separate the swell component from the wind sea to see the contribution of the swell to the response. NREL's OC4 DeepCwind semi-submersible floating structure was selected and the hydrodynamic module of FAST (Fatigue Aerodynamics Structures and Turbulence) was modified to calculate the load. The responses were evaluated. The output used in the analysis was surge, heave, pitch, mooring tension, which were platform global motions. In the surge and heave analysis, swell was more affected than wind sea component mooring tension resulted in a significant effect on surge and pitch response.

1. INTRODUCTION

Researchers from around the world have been studying the performance of offshore wind structures considering extreme marine conditions. In the study of Kim (Kim 2015), the wave spectrum generated when Hurricane proceeded was modeled through UMCM(University of Miami coupled model), which is a numerical hurricane model. In order to consider the swell response characteristic of the structure, the wind sea and swell components were separated, and the structural performance of Monopile and Jacket was analyzed by separately applying hydrodynamic load by wind sea and swell. It was found that the effect of swell to the fixed structure is not significant. In this study, the same numerical hurricane model, UMCM is used to model th hurricane Ike (2008), and the environmental load simulated based on UMCM outputs was applied to the floating structure OC4 DeepCwind semi-submersible. Using the wave spectrum data of UMCM, the swell components of the wave spectrum were separated using the wave age criteriaon to investigate the contribution of the swell component to the structure response. The hydrodyn module of NREL FAST (Fatigue Aerodynamics Structures and Turbulence)(Jonkman 2005) was modified to apply the separated wave spectrum to the wave load. We examined the global characteristics of the surge, heave, and pitch motion as well as mooring responses.

2. Hurricane generated wave and wind spectrum

2.1 Hurricane Ike(2008) & UMCM(University of Miami Coupled Model)

To assess the risk of wind turbines in extreme marine environmental conditions due to hurricanes, reliable extreme offshore conditions should be considered. However, the extreme loads considered to date are guided based on the maximum wind speed, and there is a limit of the actual extreme load conditions In this study, the output of the hurricane ike (Fig.1) generated in 2008 in the southern United States through the University of Miami Coupled Model (UMCM)(Donelan 2012), a numerical typhoon model, Wave spectrum was calculated with wind and wave data from 80h to 120h

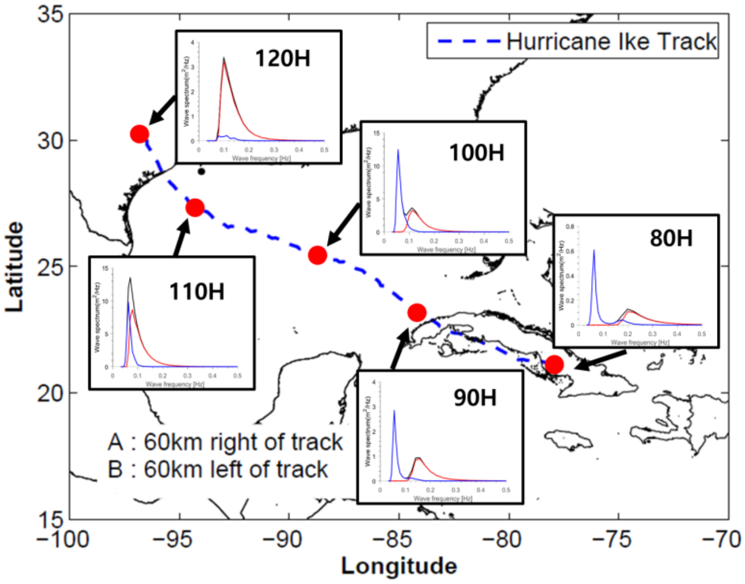

Fig. 1 Hurricane Ike track over time (blue line: swell spectrum; red line: wind sea spectrum)

2.2 Hurricane wind and swell sea separation method

The wave-age criteria was used to separate the directional wave spectra calculated from the UMCM into the wind sea and swell (Fig.2). The separation wave spectrum energy was distributed between 0.02 and 0.3 Hz, And the bi-modal type 2-peak wave spectrum is shown.

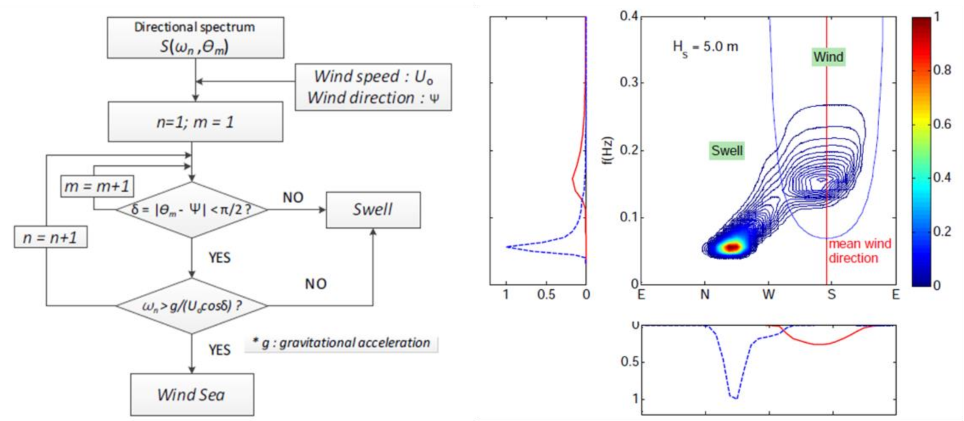

Fig. 2 Wind sea and Swell separation procedure using wave age criteria (blue line: swell spectrum; red line: wind sea spectrum)(Kim 2016; Kang 2017)

3. Offshore Wind Turbine Model and FAST

We used the NREL OC4 DeepCwind Semi-submersible model (Robertson 2014) for the floating offshore wind structure used in this study(Fig.3). The total mass of the platform column ballast and Rotor-Nacelle Assembly (RNA), the total weight of the tower and floating platforms, and the weight of the mooring system were calculated to balance buoyancy, and each characteristic was referenced in Jonkman (2009).

Fig. 3 NREL DeepCwind Semi-submersible type (Kang 2017)

The HydroDyn of the NREL FAST (Fatigue Aerodynamics Structures and Turbulence) was modified and the calculated wave spectrum was calculated by the mean direction wave spectrum prepared in Fig.2 and the added mass, Radiation damping, wave excitation force(Diffraction). We summarized the quadratic transfer function and coupled the hydrodynamic load with FAST.

4. Result

4.1 Global motion result

During the hurricane progress of 100h, hydrodynamic loads separated by total (wind sea + swelling), wind sea and swelling as load of floating marine structure are applied as PSD In Fig. 5, the displacement response according to the load case shows that the float response characteristics due to the swell load in the low frequency (LF) region are larger than the wind load. In the case of the pitch load, the swell peak in the wave spectrum and the wind sea load energy in the wind sea peak are larger than the swell load energy. In the case of surge motion, we see a large response with surge and heave NF (Natural Frequency), but the Heave motion results show a large response in the Heave NF range, Because the peak frequency is in the similar frequency range, the structural response is larger than the NF range of other structures due to the resonance phenomenon, and the contribution by wind sea load in the case of Surge and heave is clearly smaller than the Swell Heave and Pitch NF show the peak characteristics, but different from other motion responses, the Heave NF has a different response characteristic than the other motion responses. , The response was not significantly affected, and the response characteristics of Pitch were shown to be large, and it was also found that the Swell response and the peak response energy size due to the wind sea were similar

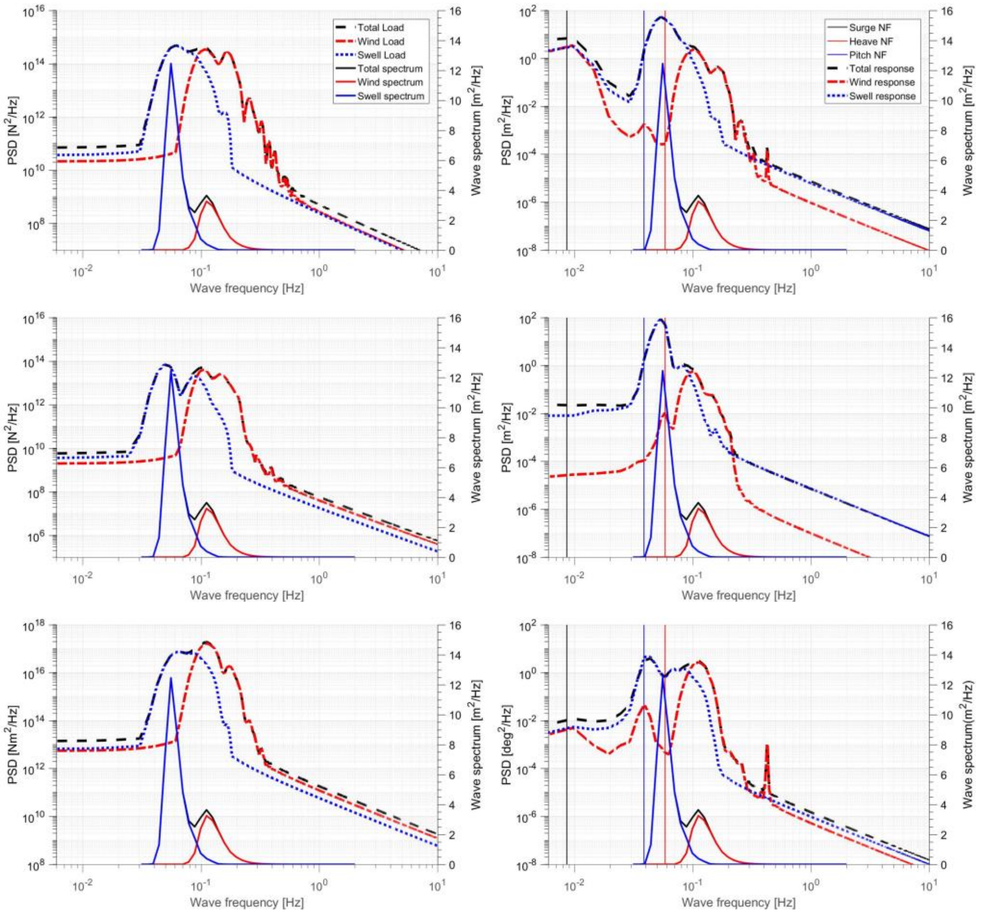

Fig. 5 Load and global response PSD(surge, heave, pitch); (black dot : Total load & response red dot : wind sea load & response, blue dot: Swell load & response, black line : Total wave spectrum, red line: wind sea wave spectrum, blue line: Swell wave spectrum)

4.2 mooring response

We analyzed the influence of the hydrodynamic load case on the mooring line at the same time as the result of the global motion. When the hydrodynamic load case acts on the 180deg, which is the front direction of the fluid part, the mooring line3 (Fair3Ten) , The mooring line 1 shows a tendency similar to the pitch motion, while the mooring line 2 shows the characteristics of the pitch motion, but the low frequency is similar to the surge motion And the response characteristics of Fig. 6

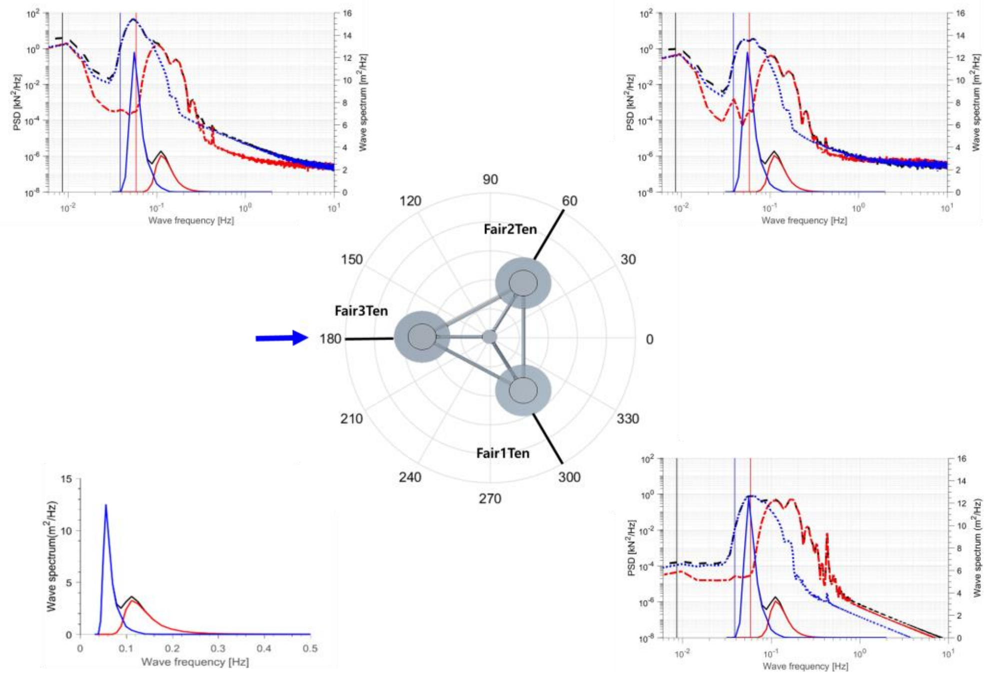

Fig. 6 Power spectrum density of tensions in the mooring lines(black dot : Total FairTen, red dot : wind sea FairTen, blue dot: Swell FairTen, black line : Total wave spectrum, red line: wind sea wave spectrum, blue line: Swell wave spectrum)

5. CONCLUSIONS

Hurricane Ike (2008) was used to generate a hurricane wave spectrum of 2-peak form through the simulation of the UMCM scenario.

In the hydrodynamic load made by the Hurricane wave spectrum, the wind sea energy is distributed in the HF region and the response is small in the case of the semi-submersible, but LF is the inherent characteristic of the fluid in the region. Since the natural frequency of the pitch is distributed, the swell of the wave spectrum shows a large response of the floating structure.

The mooring line tension response from the 180 ° direction of the hydrodynamic load has the same tendency as the surge motion response characteristic and concludes that the response of the swell component in the wave spectrum is greater than that of the wind sea component.

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