Fatigue Load on Floating Offshore Wind Turbine during Power Production
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According to IEC61400-3\textsuperscript{1}, wind turbines shall be designed for 20 years life time by using appropriate numerical simulations for a number of different external conditions. These external conditions shall be defined in term of long term joint probability distribution of wind speed, wave height, and wave period using site-specific metocean data. The combination of those parameters leads to large numbers of numerical simulations. To reduce computational effort, the effect of each wind and wave conditions on fatigue load needs to be clarified. Kvittem et al.\textsuperscript{2} studied the effect of wave period on fatigue damage on tower base of a semi-submersible wind turbine and found that the shorter wave period gives larger fatigue damage. Wang et al.\textsuperscript{3} studied the effect of wind and wave induced responses on fatigue damage and found that wave load leads to more fatigue damage compared to wind load. However, none of above researches\textsuperscript{2,3} has validated wind turbine simulation model with measurement. Furthermore, these researches only considered load characteristics at tower base section whether or not these effects are significant at tower top is still unclear. Therefore, this study aims to clarify the effect of each environmental conditions on fatigue load at tower top and base section and propose a method to reduce number of calculations needed for fatigue damage assessment based on full-scale measurement data from Fukushima wind farm\textsuperscript{4}.

In this study, load responses and environmental conditions obtained from 1-year site measurement data at Fukushima 2MW wind turbine are analyzed. To study the effect of wave height on fatigue load, fatigue loads of measurement data with the same wind and wave conditions except wave height are compared. As shown in figure.1, at tower base section it is found that fatigue load increases as wave height increases. Also, it is found that fatigue load is inversely proportional to wave peak period due to an increase in number of cycle. However, it is found that wave height and wave period have no significant effect on tower top fatigue load. According to these understanding, the equation of equivalent wave height and wave period is proposed and used to calculate equivalent wave heights and wave periods at each relevant wind speed, wind and wave directions. For directionality, measurement with different wind and wave misalignment are compared. It is found that and wave misalignment is important to be considered in calculation. To reduce number of wind and wave directions concerned in design, a criteria for selecting wind and wave direction in calculation is proposed. The results of fatigue load calculated by applying proposed method are compared to the one calculated by using 1-year time series of measurement data. The results using proposed method gives good agreement with the observed 1-year fatigue load as shown in figure.1. The number of external conditions required to consider in calculation has been reduced from 6,467 to 164 cases.

![Figure 1: (a) Effect of wave height. (b) Effect of wave period. (c) Estimated fatigue load by using proposed method.](image-url)