A Numerical Study of Wind Wave and Swell by Using Wave Prediction Models and Combined Wind Fields

Jun Tanemoto and Takeshi Ishihara
Department of Civil Engineering, School of Engineering, The University of Tokyo

Introduction

Wave predictions are necessary for the design of offshore wind turbine. The waters around Japan, large swells are caused by waves propagated over Pacific ocean. Furthermore, not only large swells but also wind waves are induced by tropical cyclones.

In the conventional studies, different wave models and wind fields for wave prediction have been proposed. In this study, at first, the conventional wave models, SWAN and WAVEWATCH III (WW3), are validated. Then, tropical cyclone induced waves are predicted by using wind field obtained from mesoscale model, typhoon model and combined wind field. Prediction methods for both wind wave and swell are discussed through these numerical studies.

Wave simulation

SWAN and WW3 are validated at Choshi offshore wind energy test site, which can be obtained observations of wave spectra.

Validation of wave fields are conducted by using observed waves at NOWPHAS Nakagusa bay, which are frequently attacked by strong tropical cyclones.

Wave height $H_10$ and period $T_10$ are predicted as follows:

$$H_10 = 4\sqrt{\frac{g}{T_10}} \quad T_10 = \frac{m_0}{m_4} \cdot \frac{\int \int f^4(\theta, \phi) \sin \theta d\theta d\phi}{\int \int f^2(\theta, \phi) \sin \theta d\theta d\phi}$$

where $E(\theta)$ is energy spectrum for frequency $f$ and direction $\theta$. Significant wave height $H_{1/3}$ and period $T_{1/3}$ are observed at both sites and following formula are used in this study for the comparison:

$$H_{1/3} = 0.956 H_10 \quad T_{1/3} = 0.54 T_10$$

Validation of the wave models

Predicted wave heights by SWAN show good agreement with observations. However, wave periods are underestimated. On the other hand, both wave height and period can be predicted accurately by using WW3.

Wave height $H_{1/3}$ and period $T_{1/3}$ of the typhoon model, the mesoscale model and the combined wind field are compared with the observed data. Predicted wave heights by using wind field obtained from mesoscale model underestimate observed wave height. These underestimations are improved by using typhoon model and combined wind field.

Validation of predicted waves by 3 wind fields

Predicted wave heights by using wind field obtained from mesoscale model underestimate observed wave height. These underestimations are improved by using typhoon model and combined wind field.

Predicted wave periods by mesoscale model are also underestimated. In contrast, those by typhoon model are overestimated before the typhoon attacked the site.

The reason are underestimations of wind waves before the typhoon attacked. As a result, wind waves are generated by the only swell by the typhoon far from the site. These overestimations are also improved by using combined wind field.

Conclusions

Numerical study for the prediction of wind wave and swell are conducted and following results are obtained.

1. Although predicted wave heights by SWAN show good agreement with observations, predicted wave periods are underestimated significantly due to underestimations of wave spectra in the low frequency range. WW3 predicts wave heights, periods and spectra correctly.

2. Predicted extreme wave height and period by using the wind field obtained from the mesoscale model underestimate tropical cyclone induced extreme wave height and period and these underestimations are improved by using the wind fields obtained from the typhoon model and the combined wind field.

Acknowledgment

This research is carried out as a part of a project funded by The New Energy and Industrial Technology Development Organization (NEDO), Japan. The authors wish to express their deepest gratitude to the concerned parties for their assistance during this study.

References