11th World Congress on Structural and Multidisciplinary Optimisation
07th -12th, June 2015, Sydney Australia

Fatigue Sensitivity Analysis of Offshore Wind Turbine Structures

Kok-Hon Chew[1], Michael Muskulus[2], Srikanth Narasimalu[3], Kang Tai[4], E.Y.K. Ng[5]

[1]School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, chew0272@e.ntu.edu.sg
[2]Department of Civil and Transport Engineering, Norwegian University of Science and Technology, Trondheim, Norway, michael.muskulus@ntnu.no
[3]Energy Research Institute @ NTU, Nanyang Technological University, Singapore, nsrikanth@ntu.edu.sg
[4]School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, mktai@ntu.edu.sg
[5]School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, mykng@ntu.edu.sg

Abstract

Design optimization of offshore wind turbine structures is generally fatigue driven, yet the fatigue damage sensitivities with respect to design variables are commonly approximated using finite difference methods, leading to inefficiency and unreliable information [1,2]. Analytical formulae for these sensitivities, on the other hand, cannot be evaluated readily. Various fatigue assessment technics (e.g. in the time-domain and by spectral methods) are available and the process to calculate the stress range histogram or stress range probability density function requires one to go through cycle counting or the Fourier transform, respectively.

This paper presents analytical methods to calculate the gradient of fatigue damage and equivalent fatigue load in both time and frequency domains, focusing on rainflow counting and Dirlik's method, respectively. Comparison studies were carried out against finite difference schemes for simulated stress data experienced by the OC4 jacket substructure, with respect to variation of step size, time step, joint configuration and stress concentration effect.

Results show that the damage gradients are very sensitive to the response sensitivities. Recommendations, which could help improve the overall quality of the numerical sensitivities, include using sufficiently small step sizes; implementing more robust time-domain methods; or adopting the semi-finite difference method. The errors associated with sensitivities for joints which the design variables are not directly connected to can be very high for the finite difference approximation. The derivatives of stress concentration factors were also found to exert a significant influence in determining the sensitivities. Therefore, this should always be considered when the hot spot stress methodology is used for the fatigue assessment.

References

[1] M. Muskulus and S. Schafhirt, Design Optimization of Wind Turbine Support Structures – A Review, *Journal of Ocean and Wind Energy*, 1 (1), 12-22, 2014.

[2] KH. Chew, K. Tai, E.Y.K. Ng, M. Muskulus, *Optimization of Offshore Wind Turbine Support Structures Using Analytical Gradient-Based Method*, Technical Report BAT/MB/OW-R01/2015, Norwegian University of Science and Technology, Trondheim, Norway, 23 pp, 2015.