Strain estimation for fatigue assessment of an offshore wind turbine using regression and modal expansion algorithms

Maximilian Henkel*[1], Wout Weijtjens[1], and Christof Devriendt[1]

[1]Acoustics and vibration Research Group - Vrije Universiteit Brussel – Belgium

Abstract

Fatigue loading of offshore wind turbines is an interaction of wave loads, wind loads and the first structural modes of a wind turbine substructure. The design of most offshore wind turbines on monopile foundation is driven by the fatigue life of the welded connections in the monopile. As a result of design optimization typically the first welds beneath the sea bed are most fatigue critical and determine the lifetime of the offshore wind turbine. Accurate information about damage progress is essential for O&M strategies but also for further design optimization while neither visual inspections nor sensor installation are feasible for those locations. Virtual sensing techniques are available to recreate strain histories and ultimately fatigue data of inaccessible locations solely relying on a limited set of response measurements from accessible locations on the structure. In this contribution regression and modal expansion algorithms are benchmarked for the use of strain estimation below mudline. The regression algorithm requires one level of strain gauges on the transition piece and subsoil strain measurements within a training period in order to recreate strains. Modal decomposition and expansion is a technique to estimate current strains based on the structural modes of the turbine. Modal coordinates are retrieved from real-time tower acceleration measurements i.e. decomposition step and applied to the substructure i.e. expansion step to reconstruct strain histories on any desired location of the monopile.

In the Nobelwind offshore wind farm situated in the Belgian North Sea three monopile foundations were equipped with accelerometers on the tower, electrical strain gauges on the transition piece and fiber Bragg gratings on several levels of the monopile. While not favorable for common use because of costly installation and maintenance provide last-mentioned sensors rarely available information about peculiarities of subsoil strains e.g. occurrence of non-linearities and non-stationary effects. Currently the Nobelwind windfarm has been operational for two years. As such sub-soil strains were recorded during a large variation of different operational and environmental conditions.

The strain signals obtained from the response estimation algorithms are compared to the actual measured strains on the submerged part of the monopile. Subsequently the algorithms are benchmarked within a long-term fatigue assessment to show potential and limitation as a tool for structural health monitoring.

Keywords: Structural health monitoring, Fatigue estimation, Virtual sensing, Measurement data, Monopile structure

*Speaker