International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 29, No. 1, March 2019, pp. 1–7; https://doi.org/10.17736/ijope.2019.mm20

http://www.isope.org/publications/publications.htm

FBG Sensors and Signal-Based Detection Method for Failure Detection of an Offshore Wind Turbine Grouted Connection

Nathalie Müller
Fraunhofer-Institut für Windenergie und Energiesystemtechnik (IWES)
Bremerhaven, Germany

Peter Kraemer
Department of Mechanical Engineering, School of Science and Technology, University of Siegen
Siegen, Germany

Dominique Leduc and Franck Schoefs
Research Institute of Civil Engineering and Mechanics (GeM), UMR CNRS 6183, Université de Nantes
Nantes, France

A fatigue test has been conducted on a large-scale offshore wind turbine grouted connection specimen at the Leibniz University of Hannover. For detecting damages in the grouted joint, a structural health monitoring (SHM) system based on fiber optic sensor-type fiber Bragg grating (FBG) has been implemented. By extracting the features of the FBG signal responses using the Wigner–Ville distribution (WVD) and one of its marginal properties, the energy spectral density (ESD), it is possible to detect the occurrence and the global severity of the damage. Some information about the local severity of the damage has also been obtained.

INTRODUCTION

The grouted connection consists of the high-performance grout-filled space between the two structural steel components of respectively the sleeve and the pile of offshore wind turbines (OWTs). For monopile OWTs, it is located around the water level between the transition piece and the pile, whereas for jacket and tripod OWTs, it is located just above the seabed, between substructure and foundation pile. While grouted joints for monopiles are exposed to bending moments, grouted joints for latticed substructures (tripods and jackets) are exposed to predominant axial loadings and low torsional moments (Schaumann and Böker, 2005; Schaumann, Lochte-Holtgreven et al., 2010). It is a critical structural part of OWTs. In 2009–2010, engineers reported grouted connection failures causing slight and progressive settlement of turbines. The problem affected approximately 600 of the 988 monopile wind turbines in the North Sea, requiring further investigations concerning the design of the grouted connection (Rajgor, 2012). Since then, two grouted connection designs reducing the axial forces in this area have been recommended by Det Norske Veritas (2014): using a conical grouted connection (first design) or a tubular connection with shear keys (second design).

With the first design, permanent vertical displacements due to axial loading will be limited with compressive contact stresses between the steel and grout thanks to the conical design. Small cone angles in the range of 1°–3° are recommended.

With the second design, shear keys (which are weld beads positioned circumferentially on the external face of the pile and the internal face of the sleeve) enable an increase of the interlocking between the cylindrical steel tubes and the grout layer. This improves the grout capacity to support shear forces due mainly to axial loading. The detail of a grouted joint with shear keys is shown in Fig. 1.

Despite new grouted connection designs that limit damages, failures may still occur; and wind turbine owners are aware of

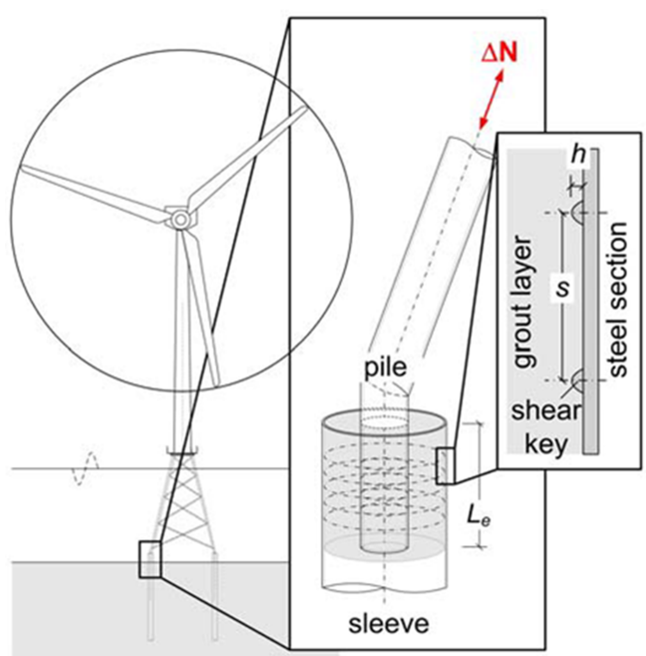

Fig. 1 OWT with jacket substructure and detail of the grouted joint (Schaumann, Bechtel and Lochte-Holtgreven, 2010)

Received October 12, 2017; updated and further revised manuscript received by the editors April 24, 2018. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-seventh International Ocean and Polar Engineering Conference (ISOPE-2017), San Francisco, California, June 25–30, 2017.

KEY WORDS: Structural health monitoring, offshore wind, grouted connection, fiber Bragg grating, Wigner–Ville distribution, energy spectral density.