Technische Universiteit Delft

Offshore & Dredging Engineering

Design, testing and verification of the DOT500 slip-joint support structure

During this MSc thesis project a full scale, real life, four meter diameter ‘slip-joint’ connection has been erected and tested on the Maasvlakte II in Rotterdam, connecting a fully operational wind turbine to its monopile foundation. Regularly, wind turbines are connected to the monopile foundation by means of a so-called transition piece. This additional piece of steel is grouted to the monopile and the wind turbine generator is subsequently bolted on top. In a slip-joint connection, a conical wind turbine tower is directly positioned over a conical top of a monopile. Hereby, a connection is created without the need for any bolts or welding, significantly reducing installation time and material costs. This is a welcome contribution to the 40% cost reduction, which is required in order to make offshore wind cost competitive with other forms of (non-renewable) electricity production.

DOT B.V. is a start-up company that has been founded with precisely that goal: make offshore wind more cost competitive by means of disruptive innovations. The current DOT500 project, a 500kW demonstration wind turbine, houses several innovations, including the slip-joint connection. Like grouted connections, static and dynamic loads from the wind turbine are transferred through contact forces between the surface contact of the two cones, mainly via friction. The structural integrity of this joint highly depends on the understanding of these load transfer mechanisms in order to quantify the effect of them in the design phase of the joint. To this end, scale experiments have been performed at the TU Delft in recent years. However, no full scale data is available up until now.

The focus of this research lies on the identification of the mechanical behaviour of the slip-joint connection, during installation and operation of the DOT500 wind turbine. Purposely, a monopile foundation was designed that allows the use of a slip-joint connection with the second hand wind turbine. A measurement campaign was organised and carried out, using several types of measuring equipment. The stresses in the slip-joint were monitored using multiple strain gauges along several circumferences over the height of the slip-joint. Additionally, several accelerometers and position sensors were installed to acquire information on the settlement of the slip-joint. Some first order models were created to predict the outcome of the measurements and acquire knowledge on the influence of the different parameters and their sensitivities on the joint.

The data of the measurements and models show promising results. The natural frequencies of the first bending modes of the total structure were identified and correspond reasonably well with the model. The settlement of the slip-joint, during installation and after a period of operation, was observed to be within predictable limits and approached a terminal level. The settlement after the installation, as a result of static self-weight only, amounts to 148 millimetres and an additional settlement of 17 millimetres was observed during the operational period of the wind turbine. The stresses within the joint, as a result of this settlement, are well below the yield stress of the material. Moreover, it is clear that in this specific case, the contact area within the slip-joint was far from optimal, as local compression was observed on the outer surface of the slip-joint. By using two purpose built cones, instead of a second hand tower, the contact area within the overlap could be improved, leading to a more desirable stress distribution.

Despite the suboptimal contact area within the slip-joint, the stresses as a result of operational loads from the wind turbine are well below the yield strength of the material and within the predictable limits. The additional hoop stresses in the wind turbine tower, as a result of a near-maximum thrust force of 70 kN, are in the order of magnitude of 20 MPa. Based on the knowledge gained from the calculations and measurements within this research, it can be concluded that the overlap length of the slip-joint connection can be shortened by at least 35% from the conventional target-level of 1.5D used for grouted connections to 1D. It is recommended to continue monitoring the settlement and stresses within the slip-joint in the next phases of the DOT500 project, especially during operational intervals. This will increase the database of valuable measurement data, thereby increasing the validity of the models and understanding of the slip-joint connection. Hence, the slip-joint connection can be used in future offshore wind turbines with confidence.

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