DOT 500 SLJ - PUBLIC REPORT

TSE HERNIEUWBARE ENERGIE 2016

Eindverslag over de uitvoering van de activiteiten en de resultaten ervan

Title: Delft Offshore Turbine slip joint tests

Abbreviation:	DOT 500 SLJ
Project number:	TEHE115072
Project period:	11/2015 – 12/2017

Consortium partners:

DOT BV (Penvoerder):	Raam 180, 2611WP Delft, the Netherlands
TU Delft:	Faculty of Civil Engineering and Geosciences, Department of Offshore Engineering

Project funding:

"Het project is uitgevoerd met subsidie van het Ministerie van Economische Zaken, Nationale regelingen EZ-subsidies, Topsector Energie uitgevoerd door Rijksdienst voor Ondernemend Nederland."

Ministerie van Economische Zaken

TOPSECTOR ENERGIE
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PROJECT SUMMARY

Background slip joint

Over the course of January 2016 through December 2017 the DOT500 SLJ project saw an full-scale slip joint being designed, installed, measured, analysed and decommissioned. After the abeyance of the technology from the nineties until 2015, TU Delft and DOT have put this technology back on the charts again by installing an actual slip joint, fully equipped with sensors to monitor its mechanical behaviour under wind turbine loads. The four-meter diameter slip joint has successfully fulfilled its role as alternative connection between wind turbine tower and monopile foundation. At the moment, wind turbines are connected to the monopile foundation by means of a transition piece, in which the connection between the two structural parts is made by either grouting or bolting. In a slip joint connection, a conical wind turbine is directly positioned over a conical monopile. In this fashion, a connection is created without the need for any bolts, welding or grouting, significantly reducing installation time and material costs.

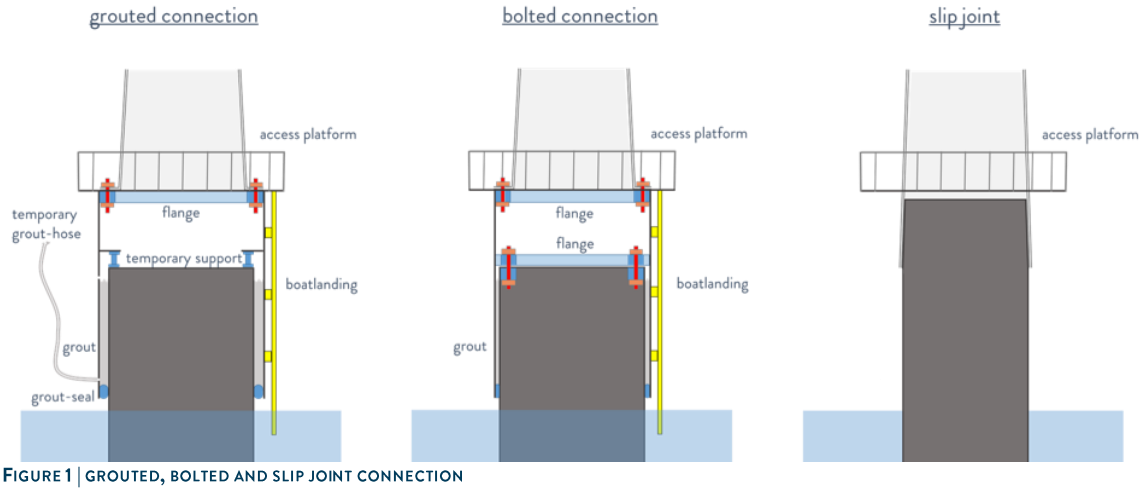

FIGURE 1 | GROUTED, BOLTED AND SLIP JOINT CONNECTION

Design, preparation and test set-up

A dedicated monopile foundation was designed by DOT and fabricated by Sif to be used as a slip joint foundation. A conical top part and 3D measurement of the slip joint contact area were realised to enable modelling and interpretation of the test results. The bolt flange of the second-hand wind turbine tower structure was removed to enable a slip joint connection. Furthermore, the tower was equipped with multiple sensors to monitor the mechanical behaviour of the slip joint during the installation and operational period. A suitable test location was found on Maasvlakte II in the Rotterdam harbour area. In a joint effort between Cape Holland, Bonn&Mees, Mammoet and F&B Windpower the monopile foundation and the wind turbine tower structure were installed. Vibro-installation technology was used to penetrate the monopile into the soil to a target depth of fifteen meters. After the successful installation of the foundation the wind turbine tower structure was installed by means of the slip joint connection.

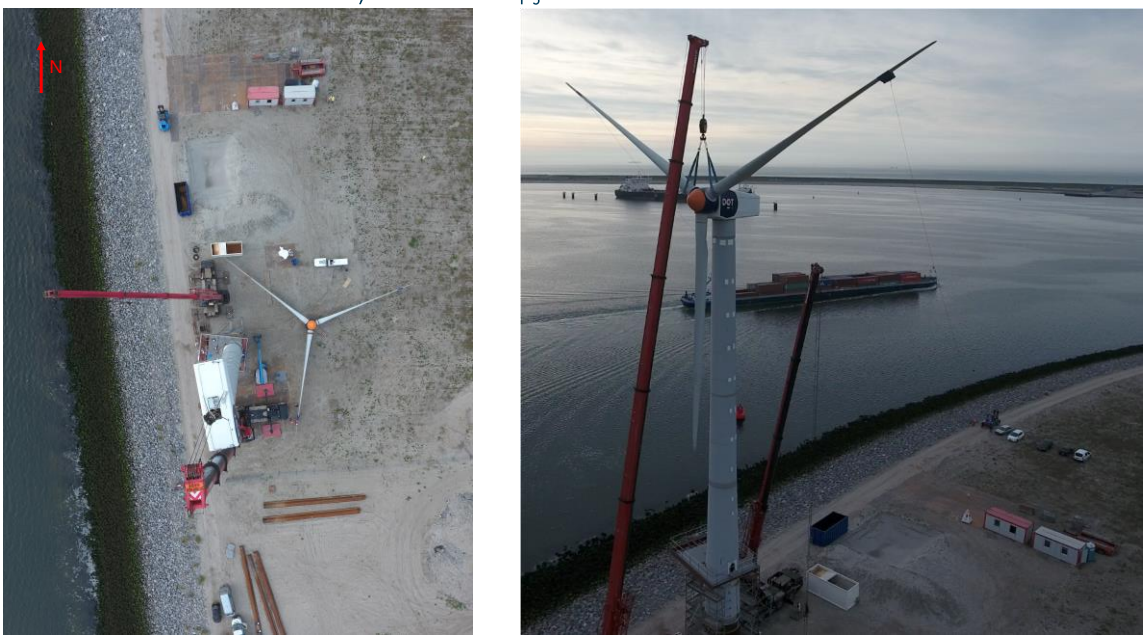

FIGURE 2 | OVERVIEW DOT TEST SITE

Results during installation and operational periods

The installation of the monopile foundation by means of the vibro-hammering technology took longer than initially expected. This can readily be explained by the lack of available empirical data to validate such studies. The target depth of fifteen meters was achieved with a slight misalignment with the vertical of about one degree. The wind turbine tower installation by means of the slip joint connection went smooth and according to plan. No complications were experienced during the installation of the slip joint, despite the out of alignment of the monopile foundation structure, proving the usability and robustness of the connection principle.

(a) (b) (c)

Figure 3 | Slip joint installation process

The data of the measurement campaign and models show promising results. 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, because 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, because of this settlement, are well below the yield stress of the material. Moreover, 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 due to the 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 slip joint principle is very suited to connect the wind turbine tower to its monopile foundation.

Workshops, seminars, courses and publications

At the start of the project, DOT organised a measurements workshop with more than thirty participants from thirteen different companies. All participants were invited to share their best ideas on possible measurement campaigns on the monopile foundation and the slip joint technology. The results from the campaigns, executed by various companies, were presented during a second seminar where eighteen participants from six companies listened to four interesting presentations and engaged in a discussion on next steps in exploiting the data. Upon project completion, DOT organised an evaluation session with all contractors involved in the installation and removal of the test set-up. The session entailed a detailed evaluation of all preparations, execution and safety related issues in general. Furthermore, two posters of project results were submitted and approved for display on the international conference “Offshore wind energy 2017”.

Next development steps

TU Delft, TNO, Van Oord, Sif Group and DOT have combined forces in the Slip Joint Offshore Research project (SJOR TEHE116334). This follow up project focusses on taking the slip joint technology to the next Technology Readiness Level using the lessons learned from the DOT500 SLJ project and the partners’ previous experiences with the slip joint connection. Within the project an actual slip joint is installed in the real offshore environment. The mechanical behaviour is investigated by means of an offshore measurement campaign and in parallel Lab studies are performed by TNO. In this joint effort the two remaining challenges of the slip joint, long term behaviour on corrosion and fatigue and distribution of contact area stresses, will be further addressed. Herewith, the TRL of the technology will be raised taking the finals steps in readying the technology for full scale commercial use, possibly already in the Borssele I-IV wind farms.