Research Abstract

Double Slip Joint – innovative foundation connection for offshore wind turbines.

Topic: Turbine technology
Sub topic: Innovations in the design of rotors, towers, support structures, foundations
Company: KCI the engineers
Presenting Author: Boudewijn van Gelder MSc, Head of KCI's Research & Development department

Introduction

In the strive of the Offshore Wind industry to become competitive with other forms of energy generation, KCI is determined to invent new solutions to bring this goal closer.

When in 2012, KCI was approached by a Dutch utility for grouting issues at one of the Dutch Offshore Wind park, KCI provided and implemented a good remedy but placed the topic on the R&D agenda in order to develop a structural solution.

Grouting or bolting of the connection between monopile and transition price are time consuming operations. Grouting issues have cost the industry a fortune up to now and the alternative of bolting, which implies the use of hydraulic tools offshore, is complicated and time consuming. They are heavy and difficult to handle. Moreover the installation of pre-tensioned bolts requires complicated procedures and the bolts need to be periodically inspected and tightened during service intervals.

With above problems in mind, KCI was determined to find a better solution for the foundation connection which moreover had to contribute to the industry's goal of reducing CAPEX and OPEX.

Approach

KCI has developed the Double Slip Joint (DSJ). The DSJ is an innovative, installation time reducing and maintenance free technology to connect monopile and transition piece for offshore wind turbines.

In December 2013 KCI initiated a research program together with the TU Delft. Several alternatives for grouted connections were studied. The comparison included flanged connections and the conventional slip-joint as used the manufacturer Windmaster for onshore wind turbines in the 80's and 90's.

A Multi Criteria Analyses was performed and KCI also included some new concepts in this analysis. The existing standards and KCI's new concepts were evaluated against 10 criteria.

#	Criterion
1	Fabrication costs and manufacturability
2	Ease of transport
3	Ease of installation (number and complexity of equipment and handling required) and safety
4	Installation time
5	Accessibility for maintenance/inspection, repair
6	Durability

7	Environmental impact
8	Controlled force transfer
9	Full-safe redundant design
10	Ability for correction of verticality, pile driving tolerance

Fig. 1 Multi Criteria Analysis used for concept selection

KCI's idea for a Double Slip Joint came out as being a very promising concept. Numerical modelling of the mechanical settling of the joint, confirmed the self-locking behaviour. Subsequently the research team involved students from Norwegian and French universities specialised in maritime and offshore engineering.

After small scale testing 1:30 of the DSJ in 2015 and 2016, which confirmed the power of the concept, medium scale tests are planned on a scale of 1:5 in the summer of 2016.
One of the milestones we have achieved is that the DSJ is now a patented design.

The most important advantages of the DSJ are a sharp reduction in the installation time of the offshore wind turbines and greatly reduced inspection- and maintenance costs due to the robustness of the connection. In the end this significantly reduces the costs of electricity per kWh for offshore wind.

Main body of abstract

In the DSJ concept, two sets of steel rings with matching conical surfaces are integrated in the standard cylindrical tubes of the monopile and the transition piece (TP). The TP is installed by lifting it inside the monopile. Contact is made concentrated at two sets of rings, which have a small tapered angle of about 2 degrees and an exact fit. This provides a well-defined self-locking steel on steel connection after installation of the TP. The TP will automatically settle under the gravity loads and operational turbine loads within a short period of time, to reach a final stable locked condition, rigidly connected to the pile, as if 'welded' together.

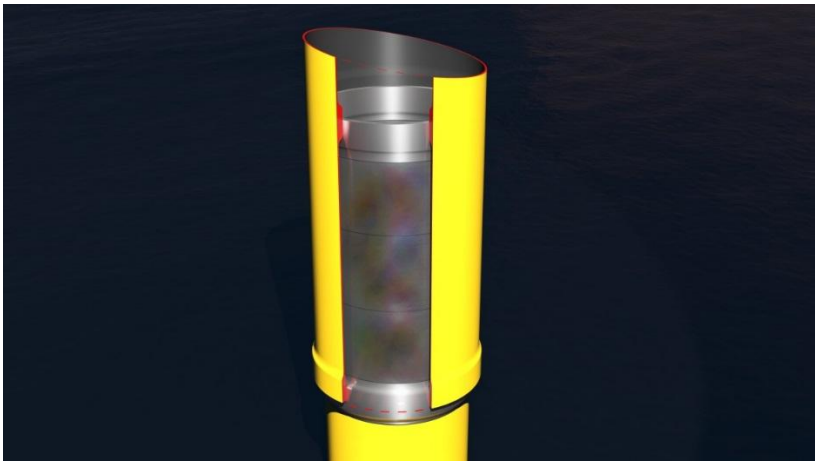

Fig. 2 Render of Double Slip Joint

With the DSJ there are two options for the connection with the monopile: above the water or below the splash zone. An advantage of the second option is that the pile length and weight is reduced, providing a better balance between the weight of the monopile and TP. Another advantage is that the complete boat landing can be pre-installed and also the DSJ under water is at the ideal location for cathodic protection of the pile, whereby the options are to use anodes or to install a 'plug and play' impressed current system.

One of the most appealing advantages to the industry will probably be the short installation time, resulting in a sharp decrease of installation costs. The TP will automatically settle on the monopile after the wind turbine has been installed due to operational loading. There is no need to inject grouting material and waiting for it to cure, neither to install bolts to be tightened. This saves an immense amount of time and presence of expensive installation vessels at sea. Fewer manual handling activities offshore, leads to enhanced safety. Further no maintenance is required on the connection. An additional cost saving factor is the ease of fabrication as cylindrical rolled plates are being used instead of cones or expensive flange connection

Conclusion
The DSJ provides a robust and cost effective alternative for the connection of the offshore monopile, transition piece and turbine tower.

Learning objectives
In creating new solutions for the Offshore Wind industry, it is important to have an exact goal in mind. The objectives KCI formulated before we started the development of the DSJ, was to create a concept which is robust, maintenance free and easy to fabricate and to install in order to generate substantial cost savings as an attempt to contribute to the industry's goal of making offshore wind more economical.

Subsequently, as an engineering company it is important to check your concepts with other industry players which in future might fabricate or install your new concept, which KCI did. We now work closely together on the next development steps of the DSJ with a large and experienced EPCI company, active in the Offshore Wind industry, and a manufacturer of monopiles and transition pieces which has led to optimisation of the DSJ concept.

Biography
Name: Boudewijn van Gelder

Boudewijn is Head of KCI's Research & Development department. The combination of his creativity and eye for innovation has led to various innovations and patents. His 29 years of offshore experience in R&D and design projects is of great value to KCI to which he committed himself nine years ago.

Boudewijn has knowledge of all the engineering disciplines at KCI but majors in mechanical and structural engineering.

Within his R&D department, Boudewijn guides students from Technical Universities with their graduation thesis and challenges them in a professional and pleasant way.