Smart alternative for grouted and bolted connections

TECHTALK

KCI'S DOUBLE SLIP JOINT

Grouting or bolting of the connection between monopile and transition piece belong to the past with the introduction of Dutch engineering company KCI's Double Slip Joint. KCI is completely convinced about this after completing intensive research. The company introduced their new concept at the EWEA OFFSHORE event in Copenhagen last month where it attracted a lot of attention. Offshore WIND spoke with Boudewijn van Gelder, Manager Research & Development and Dirk Pulles, Business Unit Manager Renewables at KCI to find out more.

Mr van Gelder, the godfather behind the concept explains: "Both grouting and bolting are time consuming operations. Grouting issues have already 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 again during service intervals."
In 2012, KCI was contracted for the Dutch Prinses Amaliawindpark to come up with solutions for the grouting issues over there. "We provided and implemented a good remedy, but also placed this topic on our R&D agenda to find alternatives for grout," he adds.

In December 2013, the opportunity came up for an initiative with the Delft University of Technology (TU Delft). As a result a student's graduation thesis project was set up to study several alternatives. A comparison included, amongst others, the existing concept of a slip-joint, as used onshore

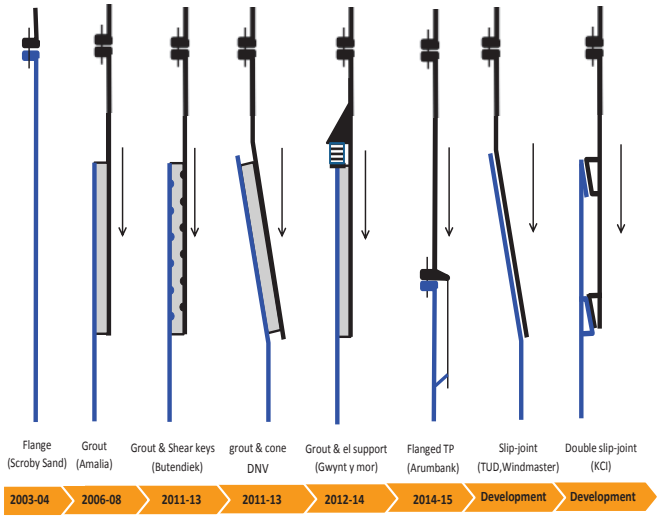

Fig. 1 Evolution of monopile – transition piece connections

by turbine manufacturer Windmaster during the 80's and 90's, and flanged connections, which at present can be seen as the industry standard for the offshore wind industry.

Multi Criteria Analyses

A Multi Criteria Analyses was performed for the selected existing options and the company included some of their own new concepts in this analyses and evaluated the existing standards and their new concepts against 10 criteria (Fig. 2). Mr van Gelder: "Our own idea for a Double Slip Joint came out as being a very promising concept and later the graduation thesis concluded with a concept design based on numerical modelling of the mechanical settling of the joint, confirming the self-locking behaviour."

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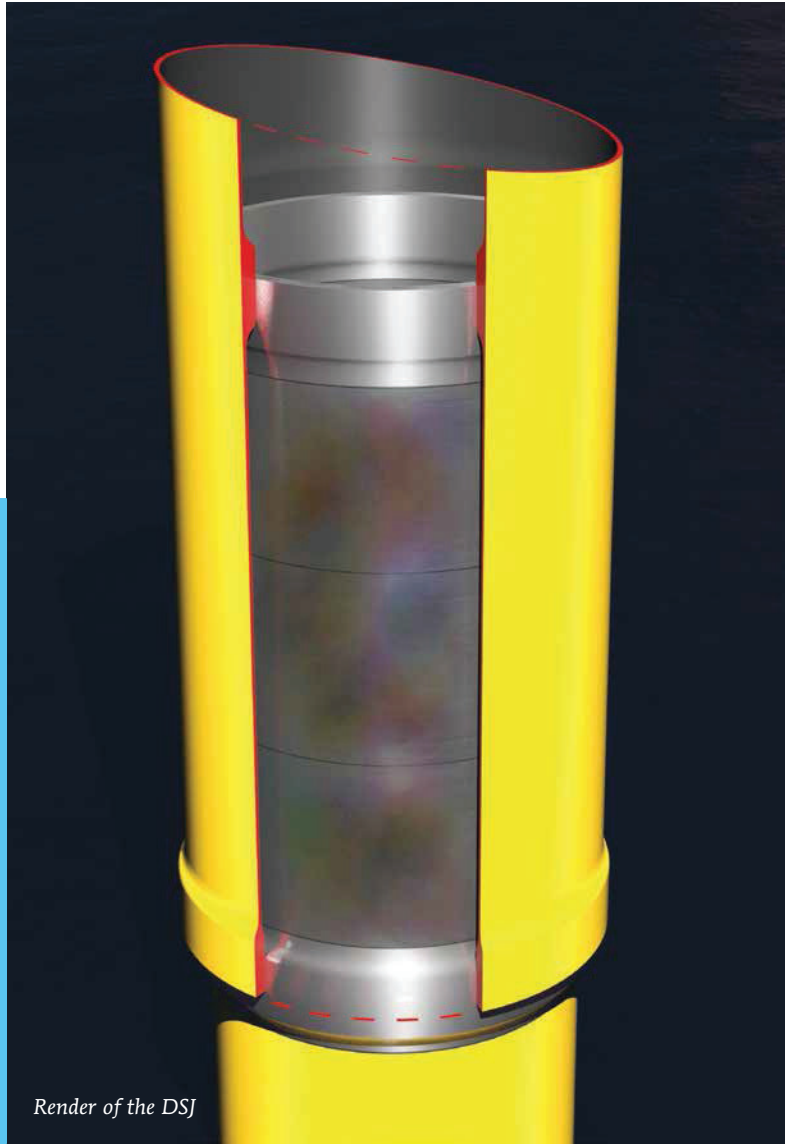
	CRITERION
1	Fabrication costs and manufacturability
2	Ease of transport
3	Ease of installation (number and complexity of equipment and handling required) and safety
4	Installation time
5	Accessibility for maintenance/ inspection, repair
6	Durability
7	Environmental impact
8	Controlled force transfer
9	Full -safe redundant design
10	Ability for correction of verticality, pile driving tolerance

Fig. 2 Multi Criteria Analyses used for concept selection



Render of the DSJ

International research team

In the meantime it is no longer a single student working on the Double Slip Joint (DSJ) concept. The company has set up a research team of KCI engineers and several Master students from TU Delft and from Norwegian and French universities specialised in maritime and offshore engineering. "The complete research study made before we came to this concept, consists of quite a thick stack of paper and just now we are preparing scale model tests. The enormous steps we have made up to now are very exciting. One of the milestones we achieved already is that the DSJ is now a patented design," he explains.

"The design objectives that we 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."

How does the DSJ work?

In the DSJ concept, two sets of steel rings with matching conical surfaces are integrated in the standard cylindrical

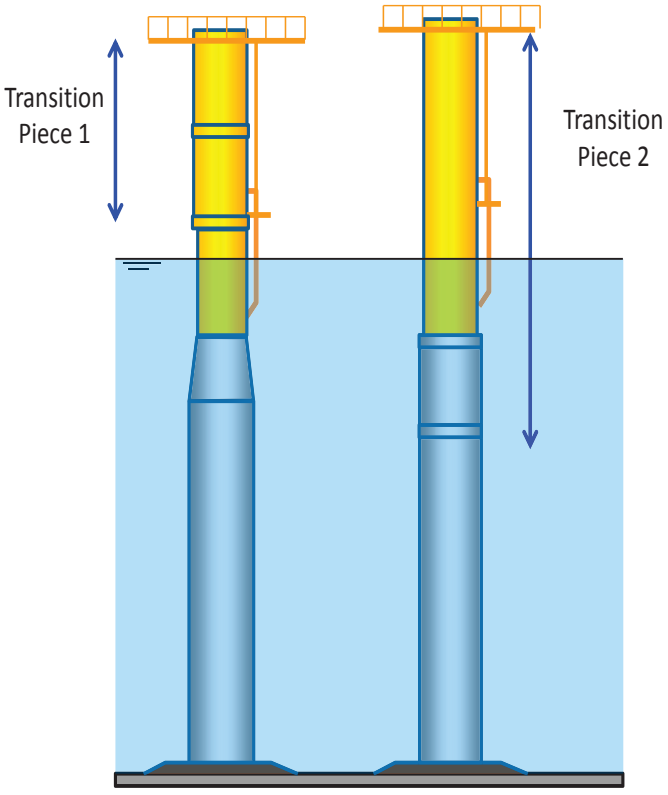


Fig. 3 Options for above and below water connections

"The DSJ saves an amount of time and presence of expensive installation vessels at sea."

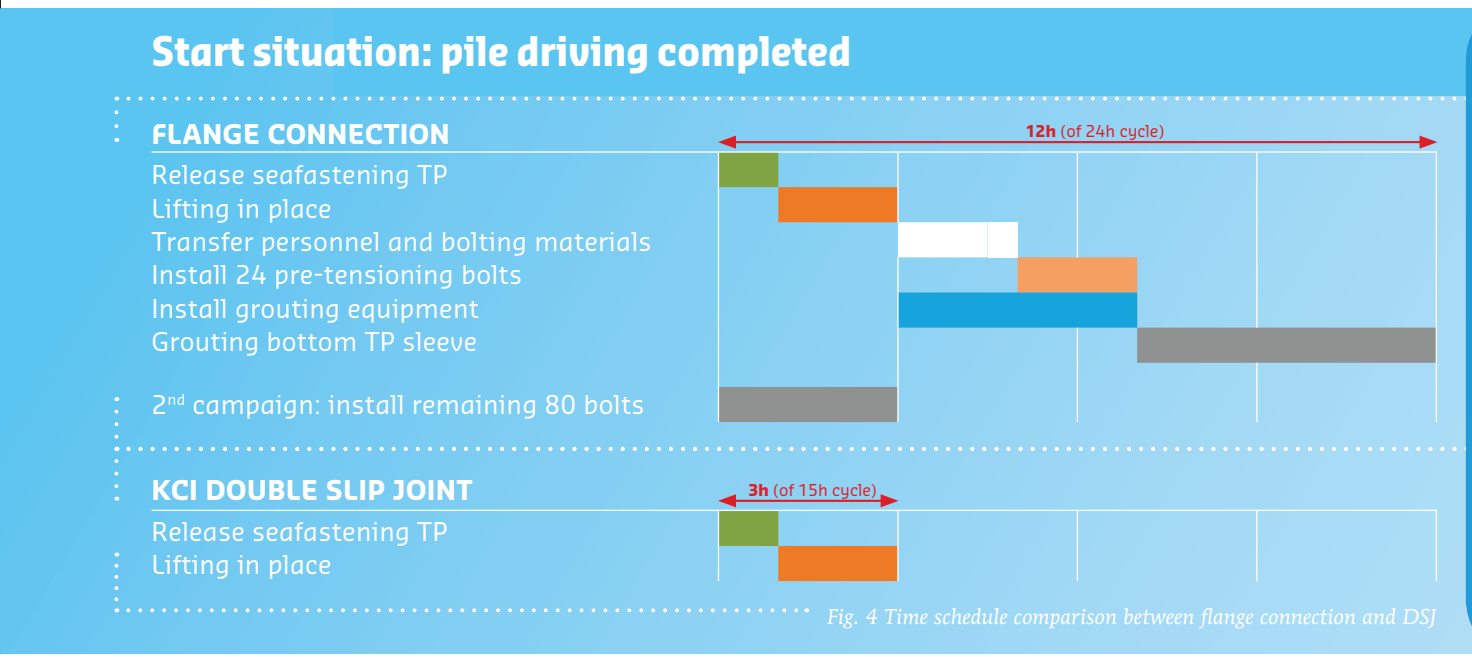


Fig. 4 Time schedule comparison between flange connection and DSJ

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tubes of the monopile and the TP. The TP is installed by lifting it over the monopile. Contact is made concentrated at two sets of rings, which have a small taper 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 tower, nacelle and blades can be installed immediately. In the DSJ concept, 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.

Under water connection possible

With the DSJ there are two options for the connection with the monopile: above the water or below the splash zone – the so-called 'inverted' DSJ. 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. Also the conical section in the monopile, which increases the diameter and strength of the pile at the base, is replaced by the inherent increase in diameter of the DSJ.

The option of the inverted DSJ 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. After installation gaps do not exist internally as there will be very little oxygen, and therefore no need for internal protection.

Advantages of the DSJ

The advantages of the DSJ are quite impressive. One of the most appealing 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. Mr van Gelder: "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."

Also safety is enhanced by using this concept as there are fewer manual handling activities offshore during installation and 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 connections.

Installation time reduced by 30%

KCI took a typical project as an example to compare installation time of the planned bolted connection with the DSJ concept. The installation schedule of the conventional flanged connection takes a cycle of at least 24 hours per foundation. The jack-up installation vessel requires about 12 hours for installing the TP and 12 hours for other

activities such as jacking up/down and relocating to the next location in the wind farm. This cycle time will be significantly shortened, as the TP can be installed in only 3 hours instead of 12, saving 9 hours in the 24-hour cycle.

The direct effect is that costly installation vessel and support vessels can be shorter under contract. Moreover, a complete wind farm of e.g. 80 foundations can be installed in one summer season before deteriorating weather slows down the end of the installation project or even pushing it to the next spring season.

Development stages

KCI's Business Unit Manager Mr Pulles tells: "We launched the DSJ concept last month during the EWEA OFFSHORE event in Copenhagen and were overwhelmed by the positive

Boudewijn van Gelder

Dirk Pulles

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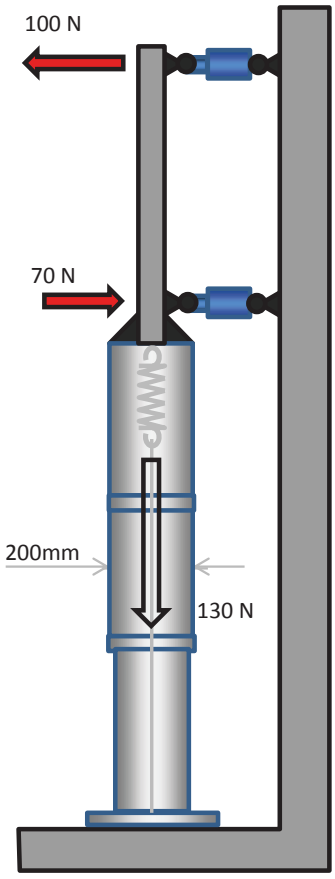

Fig. 5 Scale test set up

response. Offshore turbine manufacturers came to our stand and complimented us with our design, calling it even 'the winning design'! But we also received interest from an insurance company. The grouting problems have cost the industry an incredible amount of money so such an interest is therefore quite logical. But these were not the type of people that normally visit our stand!"

At this moment a scale test set up is under development which is planned to be finalised in August this year. The purpose of the test set up is to verify the settling behaviour under turbine loads found by the Finite Element model. The scale will be sized down 1:30 but with similarity of geometry, deformation and material properties.

Also in 2015, the certifying tests are scheduled and a decision will be taken on possible cooperation with one or more partners. By the end of 2015 the development of the engineering demo prototype will start, followed in early 2016 by the fabrication of the full scale demo prototype to be installed by mid 2016.

Offshore WIND will keep you informed on the developments of the DSJ. Read more about the topic on foundations in general in the next edition of Offshore WIND.

With thanks to Boudewijn van Gelder, Manager Research & Development, Dirk Pulles, Business Unit Manager Renewables, and Marika van Pol, Marketing Manager at KCI the engineers B.V.