

Double Slip Joint

Innovative foundation connection for offshore wind turbines

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Abstract

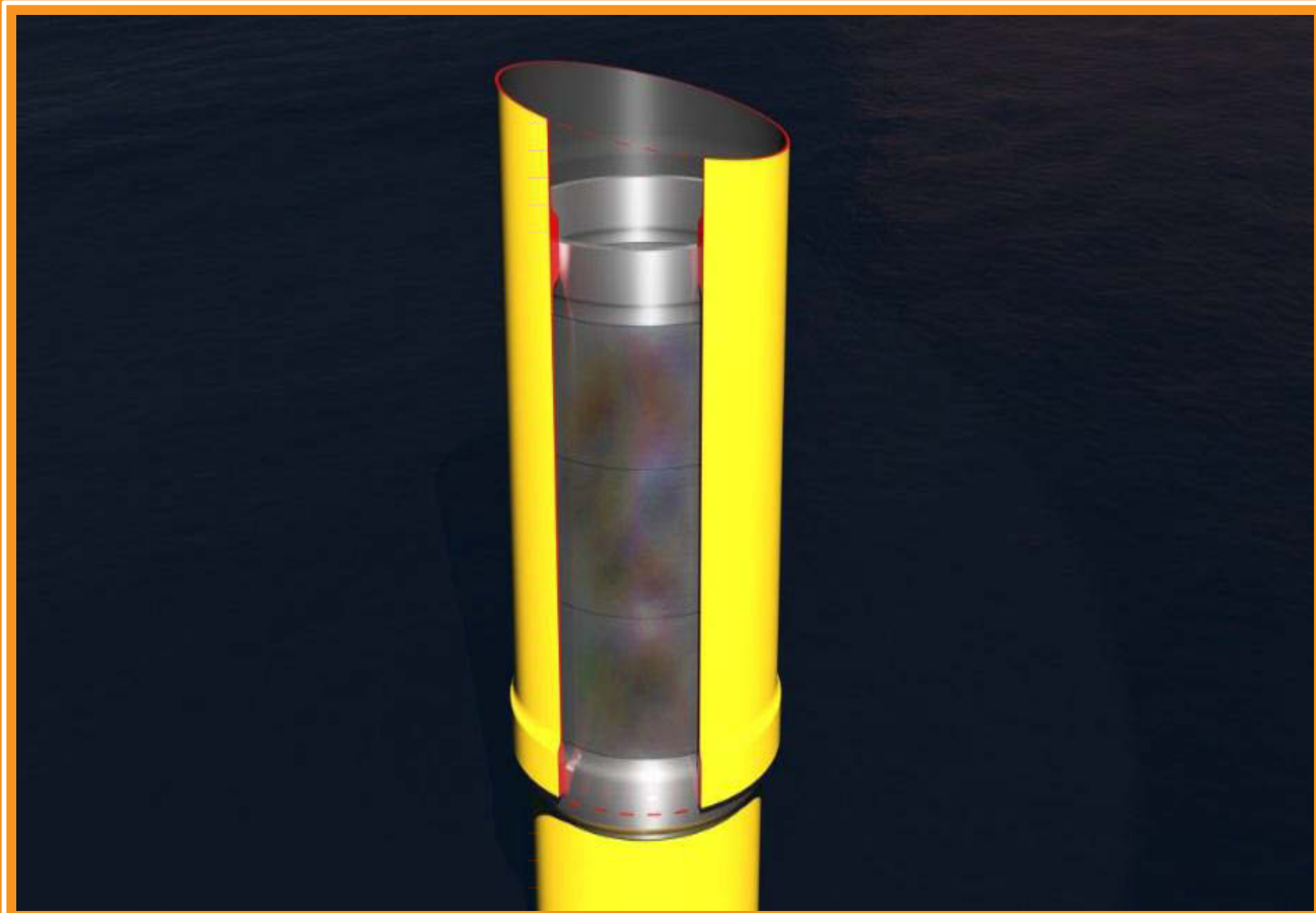
In the strive of the Offshore Wind industry to become competitive with other forms of energy generation, KCI is determined to invent new solutions to bring this goal closer.

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 piece 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.

In KCI's Double Slip Joint (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.



Objectives

Cost savings & maintenance free concept

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.

Optimisation concept by iteration circle with industry players

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.

Methods

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.

Multi Criteria Analysis used for concept selection

#	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

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.

Conclusions

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

