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Case Study

Pile Gripper FEED Study

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Tags:
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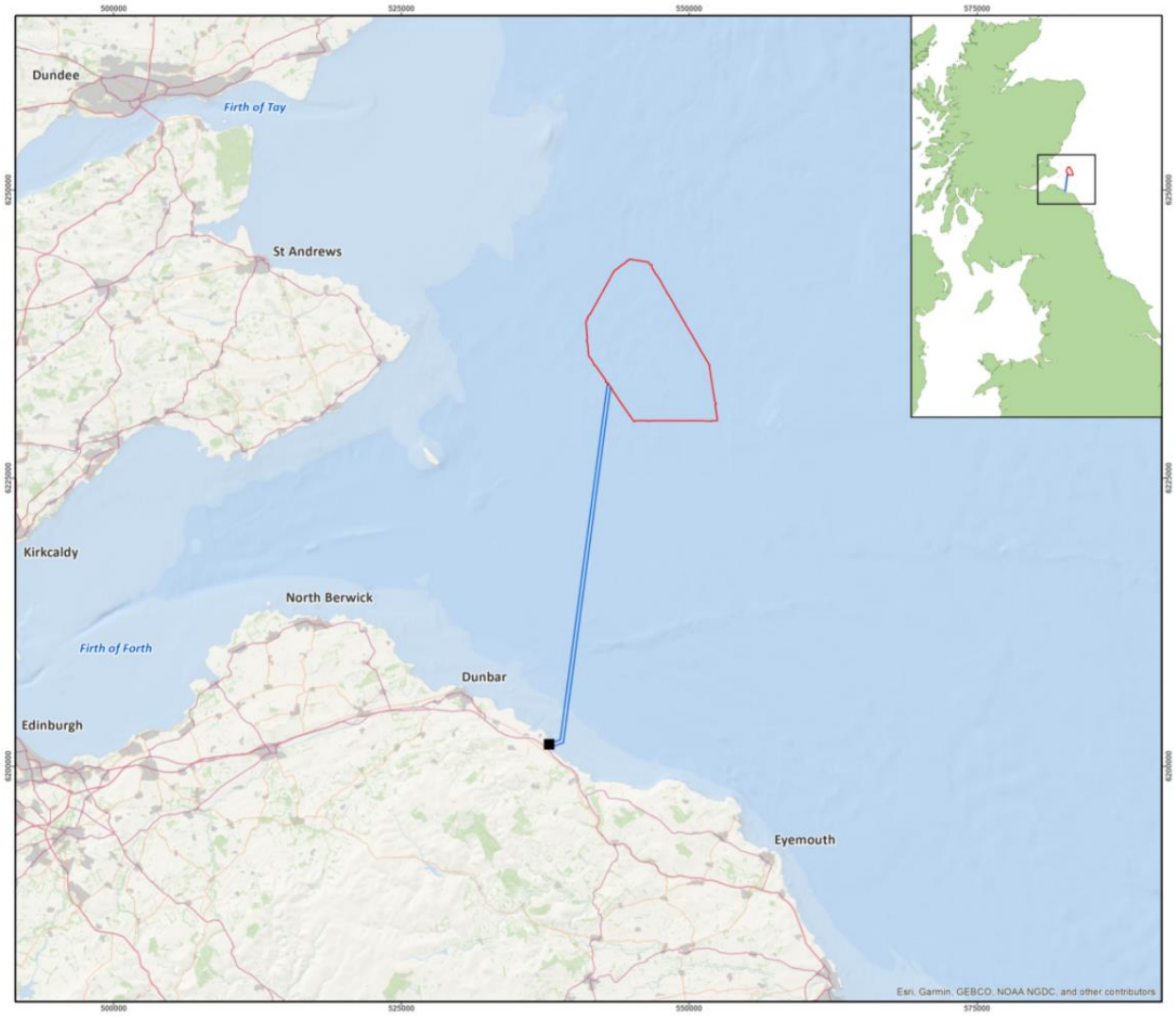
Design
Offshore Wind
Renewables
DNV Standards
Pile Gripper
Jacket Structure

1 Background

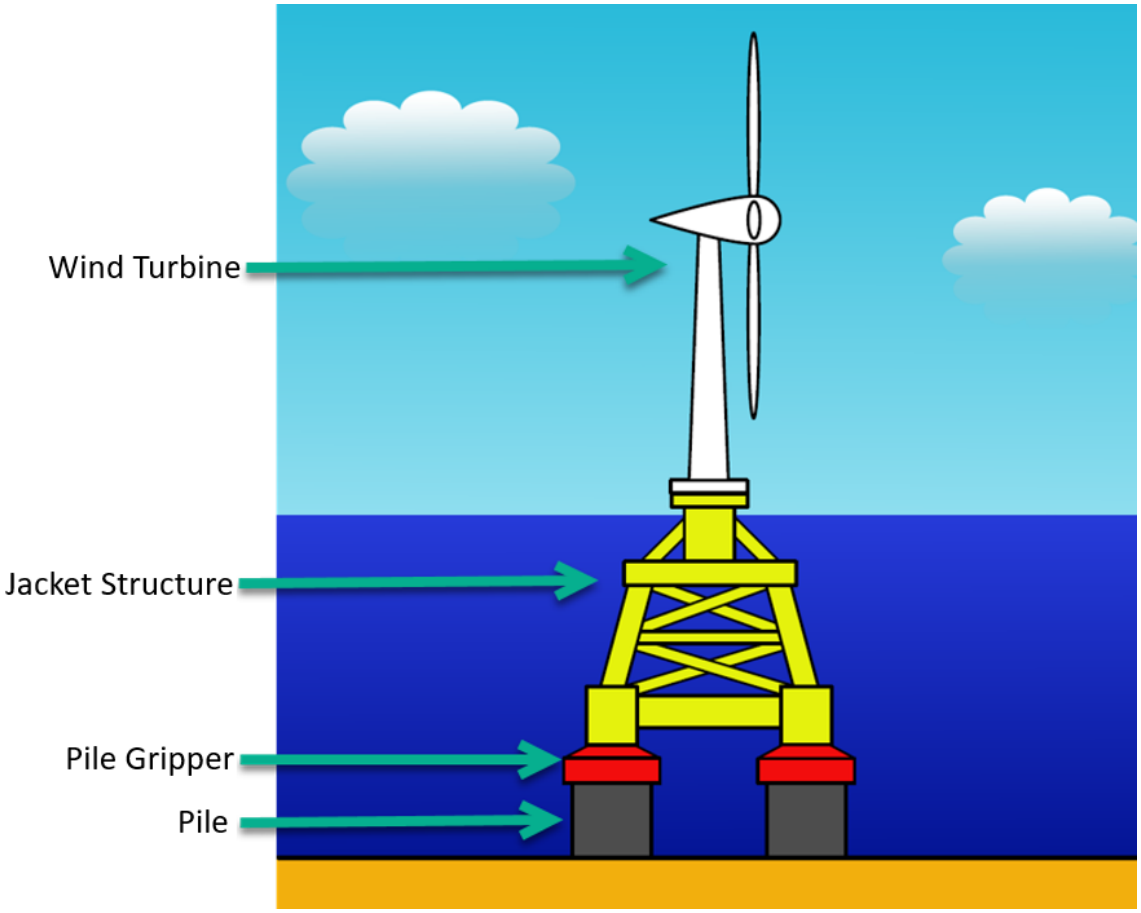
The installation of offshore wind farms is progressively increasing to maximise renewable energy production and decarbonise the grid. There is a continued focus to ensure the system's structural integrity is optimised to improve the wind turbine's end of life duration. An essential part of the installation process is using a pile gripper to ensure the jacket is positioned securely while the grout cures. Failures in this process can be extremely costly and result in a significant delay. The Energyst [1] estimated that grout installations, before the DNV standard update, lead to 14 UK Offshore wind farms having defect issues. There has even been a court case involving the Robin Rigg offshore farm to determine the liable party for faulty grouting. [2]

The client contracted Armech Solutions to analyse a Novel Pile Gripper system for the Offshore Wind Industry; they have a firm footing within the industry, specifically offshore handling systems, undertaking design, manufacture, and systems supply. The client designed a concept pile gripper to surpass the performance of the conventional market offerings. The new design was motivated by a recent modification to the DNVGL-OS-J101 standard, specifically the grout early age cycling requirement. The project was primarily for the Neart na Gaoithe wind farm located off the Fife coast [3], however, with the outlook of mass deployment of the technology.



The original design, alongside the client's novel pile gripper, require in-depth FEA and review, which Armech Solutions will assess against the updated DNVGL-ST-0126 standard. Due to Armech's strong analysis skillset and longstanding relationship with the client, we assisted by undertaking the project and increasing their engineering capacity with our specialist simulation skillset.

Offshore wind turbines are typically installed on steel jacket structures. The first step is to install piles into the seabed through pre-pilling templates; then, the jacket structures are landed on the piles and grouted. Before the grouting operation, pile grippers secure the jacket structures to the piles and levelling cylinders ensure the jacket is in the correct position. The pile grippers allow the jacket to be balanced, preventing movement relative to the pile while the grout cures. Pile Grippers provide stability during the grouting operation that permanently fixes the jacket in situ. The illustration indicates the position of the pile gripper within the structure.



The movement of the jacket leg relative to the pile gripper, referred to as Early Age Cycling, can lead to crack formation within the grout when allowed to take place beyond the specified allowable distance. This crack can significantly reduce the structure's performance and lead to reduced shear capacity of the configuration. Future systems, therefore, require modification to ensure they remain secure for their intended lifespan.

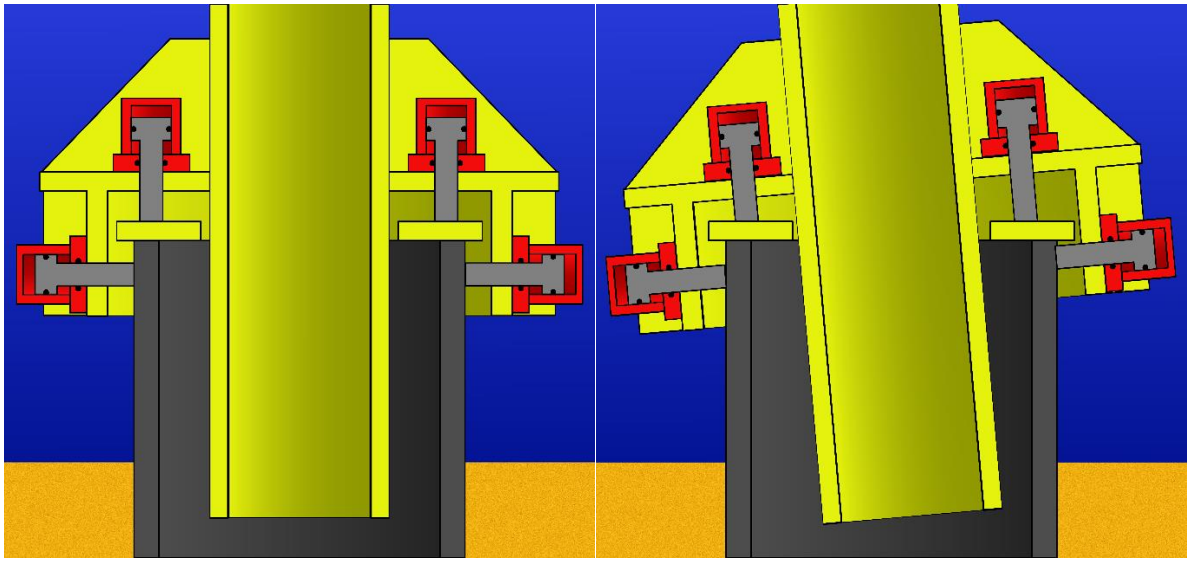
2 Problem

Due to the sheer size of these structures, the pile gripper must withstand tremendous forces and moments. Even if the Pile Gripper is strong enough, there is a risk that relative movement between the jacket leg and pile will cause defects in the grout as it cures. Subsequently, there is a risk that these defects may lead to instability of the jacket structure over its lifetime. The table demonstrates the significant boundary conditions that form the basis of the analysis.

Wave Period	Wave Direction	Load Case	Force x	Force y	Force z	Resultant	Moment x	Moment y	Moment z	Resultant
			kN	kN	kN	kN	kN-m	kN-m	kN-m	kN-m
6.5	210	18 Max	-1900	441	231	498	0	305	564	642
		18 Min	444	-107	-62	124	0	-82	-146	167

Jacket structures placed into piles were previously limited to relative axial movement of 1mm by DNV-OS-J101 during the 24-hour curing period. However, the standard has been superseded by DNVGL-ST-0126, limiting relative movement in any direction to 1mm. The motivation for this change is to prevent early age cycling of the grout. Due to the update in the DNV standard, conventional pile

grippers may no longer be acceptable. The following illustrations present the potential flaw that can arise with the current pile gripper design.



The conventional pile gripper utilised gripping cylinders in a horizontal and vertical configuration at the top of the pile and around the jacket structure; however, this does not address relative motion where the jacket leg protrudes into the pile.

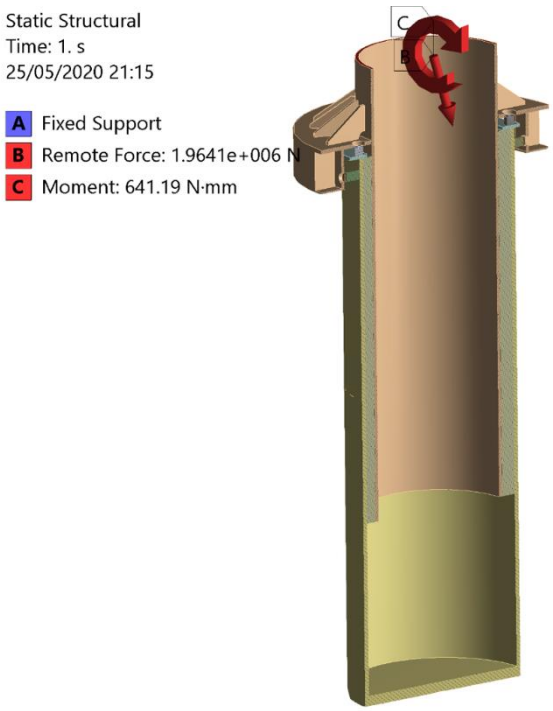
The novel pile gripper system, designed by the client, must be assessed by employing FEA against the updated DNV standard and compared to the performance of the conventional Pile Gripper.

3 Solution

Armech Solutions modelled a highly idealised structure due to the analysis being preliminary and primarily for comparative purposes. The model included the pile, jacket leg and pile gripper system. The client requested the analysis is run with minimal simulation time, and therefore Armech employed the use of joints as opposed to contacts.

Armech identified that a coarse mesh would be suitable since deformation was the primary output as opposed to stress. Design iterations and improvements were therefore efficient as the client was able to receive results quickly.

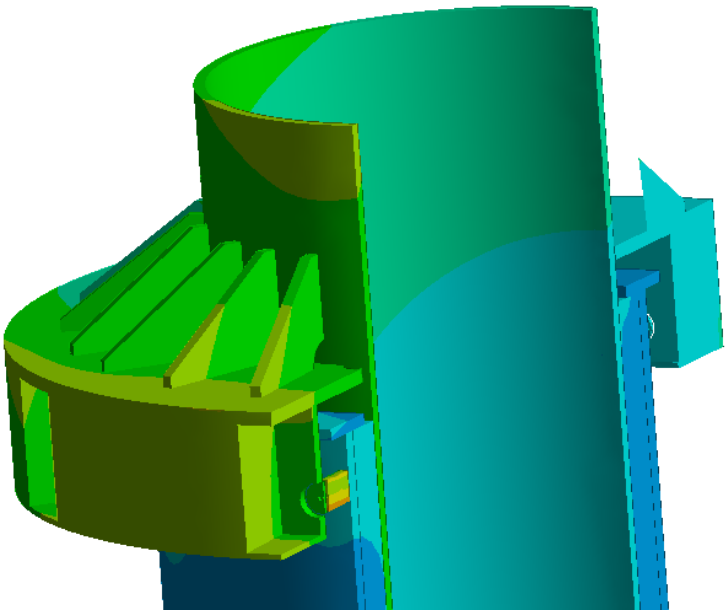
Using client geometry and load-case data, we constructed two identical models: one using a traditional pile gripper and one using the client's novel concept. Springs simulated the hydraulic pressure acting on the cylinders used in the assembly, with the spring stiffness based on the spring rate of the hydraulic fluid used in the system. A frictional contact represented the clamping cylinders' interface with the pile. Triaxial forces and moments were applied to a node connected to the jacket leg.

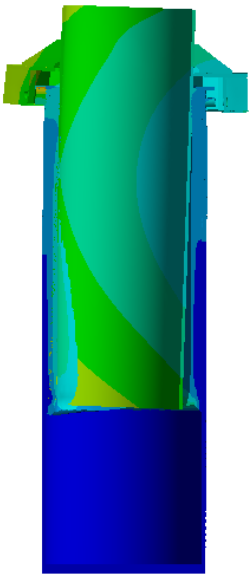


The objective of the analysis was to determine the maximum relative movement between the pile and the jacket leg; this was obtained by probing nodal displacement.

4 Results

The project successfully demonstrated that the client's novel pile gripper system could satisfy the early age cycling criteria defined by DNVGL-ST-0126. Conventional pile gripper systems have inherent design flaws that could cause grout integrity issues (as defined by DNVGL-ST-0126). Contour plots show the FEA results for the traditional pile gripper design where the deflection of the jacket section inside the pile surpasses the 1mm allowable.





The integrity issues arose due to the portion of the jacket structure placed into the pile that acted as a cantilever leading to movement and potentially early age cycling of the grout. The client used the analysis results to produce a tender document. The quantitative nature of finite element analysis allowed them to present a robust technical argument favouring their proposal and illustrate the potential improvements compared to a standard pile gripping system. Based on the load cases considered, it was demonstrable that conventional gripper systems are limited in applications, according to DNVGL-ST-0126.

5 What Next

Armech Solutions has a long-standing relationship with the client; we continue to provide our expertise regularly for their marine and renewable business.

We are continuing to build on the relationships with our clients in the renewables sector, and we are motivated to assist new clients with our analysis and design skills in the future.

[1] Grout expectations: Eon takes offshore wind hit (theenergyst.com)

[2] eon-victorious-in-robin-rigg-case - reNews - Renewable Energy News

[3] Neart na Gaoithe Offshore Windfarm (Revised Design) - MS EPS 16 2019 0 - Application | Marine Scotland Information

[4] Harland & Wolff to build Neart na Gaoithe offshore wind farm jackets | Offshore (offshore-mag.com)