Creating land for the future
The only source of knowledge is experience

Albert Einstein
DEME │ Jack-Up Risks

WHICH LESSONS COLLECTED IN EUROPE SHOULD BE EXPORTED GLOBALLY?

Creating land for the future
Europe

- Average installation time of MP foundations has decreased since the “early days” of offshore wind

<table>
<thead>
<tr>
<th>Monopile installation time</th>
<th>Vessel days/foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009 - 2013</td>
<td>4.24</td>
</tr>
<tr>
<td>2014- 2017</td>
<td>2.39</td>
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</tbody>
</table>

source R. Lacal-Arantegui et al.

- Introduction into the market of larger vessels; Pacific Orca, Pacific Osprey, Vidar, Aeolus, Scylla, Innovation,…

- Consolidation of experience with offshore wind jack-ups?
Offshore Wind Jack-up Vessels

- Minimum 4 legs
- Statically undetermined
- Preload/Predrive on diagonal
Offshore Wind Jack-up Vessels

- Minimum 4 legs
- Statically indetermined
- Preload/Predrive on diagonal
- No additional ballast
- Controlled penetration
- Load at footing:
  - Tubular legs ~ 3000 kPa
  - Spudcans ~ 400 – 1000 kPa
- Fast deployment / short term residence
Challenges in Europe

Punch-through
• During preloading
• Scour induced
• Plugging?

Silt behaviour
• Drained vs undrained
• Cyclic degradation

Leg extraction feasibility
• Soil sensitivity
• Jetting systems

Site knowledge
• Data
• Experience

Footprints
• Interaction
• Shape
• Influence on foundations
Punch-through – Tubular - Optimisation of calculation methods

- Layered soil – sand over clay
- Neptune tubular leg 3.5m OD
- Punch-through risk

- Risk: Excessive leg penetration in case of punch-through during preloading
  - Extraction risk
  - Insufficient leg length

- Challenge: proof that Neptune can operate the site
- Trials with Neptune on its maiden voyage
- “load-spread agle” reanalysed based on trial data
Punch-through – Tubular - Optimisation of calculation methods

Figure 3. Interpreted soil profile at Trial 1 location.

Figure 6. Predicted and measured penetrations at Trial 1.

(Kort et al 2013)
Punch Through – rack & pinion – developing engineering perspective

► Knowledge from tubular JUP’s with hydraulic system
► First project with rack & pinion vessel
► Focus on lessons learnt in Oil & Gas industry
Punch Through – rack &

- knowledge from tubular JUP’s with hydraulic system
- First project with rack & pinion vessel
- Focus on lessons learnt in Oil & Gas industry
- Avoid falling into time consuming & expensive scenario’s as proposed in Oil & Gas guidelines

Table 6.2: Recommended preloading strategies for spudcan installation in strongly layered soils

- Consider relocating the installation site.
- If relocation is unfeasible the upper strong layer could be weakened until punch-through potential is eliminated prior to installation (refer to Sections 5.3 and 5.4). If installation alongside a structure then the furthest leg(s) should be preloaded first (usually bow) so that hull movements due to unexpected leg penetrations will be away from the structure. The preloading should be according to leg-by-leg preloading procedures.

- An assessment of the controllability of the potential leg plunge during the punch-through in terms of jack-up structural integrity should be considered.
- Sequential preloading with the hull in the water with suitable weather window with minimal wave action is available. Cautious preload application is required as the load approaches the peak bearing resistance. Also be aware of potential set-up effects.
- If installation alongside a structure then the furthest leg(s) should be preloaded first (usually bow) so that hull movements due to unexpected leg penetrations will be away from the structure.
- Ensure that final leg penetrations are such that the spudcans are safely supported in the lower soil layer.

(InsafeJIP 2011)
Punch-through – a typical case

![Graph showing penetration and Spudcan reaction for Leg 1 and Leg 2 over time. The graph highlights a period of 7 minutes where the Spudcan reaction is significantly different between the two legs.](image-url)
Scour risk

- Tubular with spudcans
- Site with large tidal currents
- Initial penetration during preload = prediction
- Shakedown during operation
  - anticipated in SSA – no PT risk
  - Intermediate levelling to stay within tolerance of inclination
  - Weather restricted operation
Silt behaviour - Cyclic mobility

- Difficult from experience to confirm whether additional penetrations are scour related or due to cyclic degradation
- Specific lab tests to investigate phenomenon are rarely available
- Rarely specifically addressed is SSA
  - Because the risk is marginal under storm loading?
  - Will it become a more standard assessment due to experience of EQ assessments?

9.4.6 Cyclic mobility

Cyclic loads can cause a progressive build-up of pore pressures within the foundation soils and consequent soil strength degradation (liquefaction). The effects can be either local to the soils under the spudcan or over a larger area. Local foundation cyclic loading can be caused by the jack-up response to earthquakes, severe storms, rotating machinery, etc. Earthquakes can cause large-scale cyclic loading and result in failure of the soil mass over a large area. Depending on the magnitude of pore pressures developed, cyclic loading can result in large vertical displacements of the spudcans, which can be differential in some cases.

The assessment shall consider the effects of cyclic loading on the stability and displacements of foundations.
Neptune – leg extraction feasibility

.StatusBadRequest

- History of neighbouring site provided by client:
  - 2 jack-up’s stuck
    - Tubular
    - Spudcans

- Challenging site

- Neptune without spudcans
  - Deep penetrations predicted:
    - UB: 21,5m
    - LB: 29,5m
  - LB predicted shaft friction > pulling capacity
Neptune – leg extraction feasibility

Engineered approach required

► Optimise preload
  › operational conditions
  › Predicted shaft friction < pulling capacity

► Designed & Installed Jetting system
Neptune – leg extraction feasibility

- Within predictions (see also Irvine et al. 2016)
- Jetting system functioned well
- Penetrations between different legs (while same preload) different at same location
  - Variability clay strength?
- Remoulded clay penetrated in the legs
INNOVATION – Site knowledge

- No existing experience with JUP operations on in region of the site
- Large variability on soil strength
- Predicted penetration: 4 – 16m
- Large uncertainties
  - Cycle times?
  - Feasibility of extraction?
- Jacking trials scheduled
INNOVATION – Site knowledge

► No existing experience with JUP operations on in region of the site
► Large variability on soil strength
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► Large uncertainties
  › Cycle times?
  › Feasibility of extraction?
► Jacking trials scheduled
INNOVATION – Site knowledge

► Lessons learnt from trials
  › Behaviour LB
  › Time consuming
  › Jetting system = crucial for extraction
  › Extraction limited by flowrate
  › Large footprints were left

► Action plan towards project execution
  › Increase surface of spudcans
  › Increase flow rate of jetting system
  › Adapt preload procedure

(Raymackers et al., 2017)
Experience in Europe

- Every project brings its challenges
  - Multilayered soils still pose challenges for accurate assessment
  - Large variability on soil strength results in some cases in unacceptable uncertainty on leg penetration behaviour
- Decent soil investigation mostly available and provided
- Collaborative approach between engineers of different parties
Risks in Europe VS Causes of failure in Oil & Gas

- Punch-through
  - During preloading
  - Scour induced
  - Plugging?

- Silt behaviour
  - Drained vs undrained
  - Cyclic degradation

- Site knowledge
  - Data
  - Experience

- Leg extraction feasibility
  - Soil sensitivity
  - Jetting systems

- Footprints
  - Interaction
  - Shape
  - Influence on foundations

- Others
  - Punch-through during preloading/jacking up
  - Sliding of mast foundation
  - Seabed instability/mudslide/undrained seabed/volcanic activities
  - Uneven seabed/Scour/Footprint
  - Punch-through/additional penetration during Hurricane/storm

HSE RR289
Going global – jack-up risks

► Failure
  › Punch-through related
    - Scour induced punch-through
    - Cyclic (storm loading/ earthquake)
  › Geohazard related (seafloor instability, volcanic, mudslides, …)

► Delays
  › Repositioning required due to execive leg bending/RPD’s (uneven seabed, obstacles, footprints)
  › Leg extraction issues

► Damage to structures/cables/seabed
Current perceived challenges – going global

- Challenging soil conditions
- Bad quality soil data
- Partial transfer of soil data/environmental data
- Less experienced local third party consultants
Ingredients for reduced jack-up risks in Europe – ready for global export?

- Decent soil investigation
- Knowledge of boundary conditions
- Experience
  - Soil investigation jack-ups records
  - Records jacking operations at adjacent sites
  - Trials when required
- Competent third party consultants
- Right engineering perspective towards risks
- Collaboration
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