



EPSRC SUPERGEN Wind Hub General Assembly Thursday 8th November, 2018, Dundee

Dr Michael Brown, University of Dundee
PI Grand Challenge project:
Screw piles for wind energy foundation systems

<https://www.supergen-wind.org.uk/>



Our vision

- In 2014 The Supergen activities in Wind Energy were successfully renewed as part of Phase 3 Hub funding from EPSRC.
- The Supergen Hub takes a leadership role in bringing together the research efforts in Wind Energy in the UK, and linking them more strongly to the development research being supported by other funding organisations.
- The Hub received £3M in funding to September 2019 to carry out our innovative work packages.

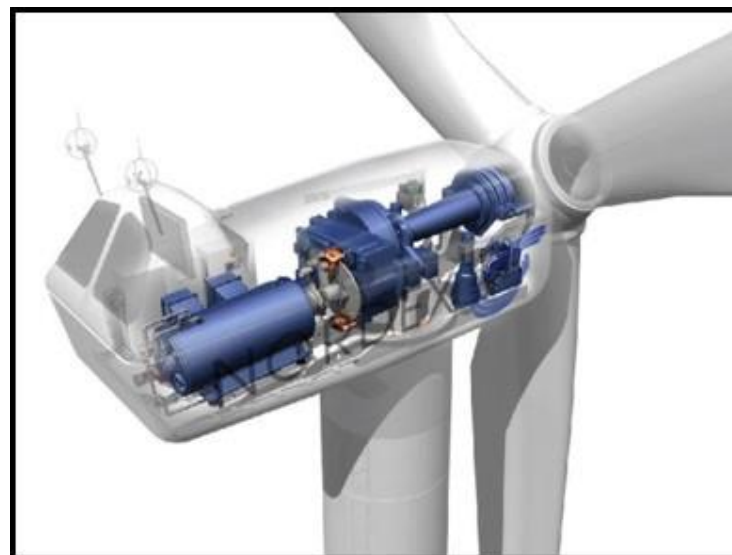




Our members

➤ SUPERGEN Wind members:

Universities of Strathclyde, Durham, Loughborough, Cranfield, Manchester, Oxford, Surrey, Bristol, Dundee, Imperial College London, Exeter, Edinburgh, UCL, Glasgow, alongside STFC, DNV-GL, OREC.





Our Impact

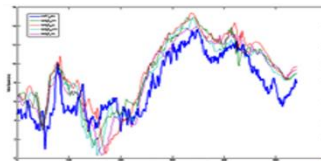


- **Research impact:** The UK academic research base has a significant international presence
- **Impact on industry:** Collaboration with industry is at both the consortium level and individual partner level.
- **Specific areas of impact:** Health monitoring, Asset Management, Control, Resource Assessment, Radar and Offshore Support Structures & Foundations.
- **Standards:** Contributions to IEA Annexes 21, 23, 25, 32 and 37, IEA
- **Study Groups** B4-57 and B4-72 and IEC 61400-1/-3 shadow panel.

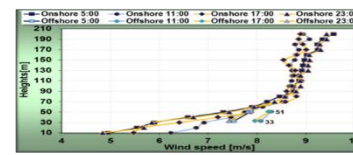
Our research scope

- Planning and Consenting
- Design, Manufacturing and Installation
- Operation, Maintenance and Decommissioning

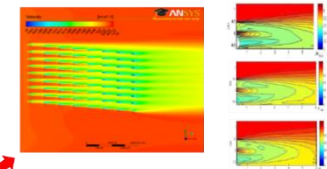
Short term resource and time series



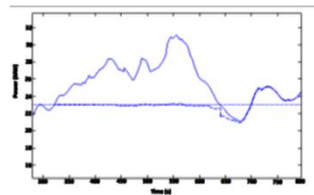
Long term resource



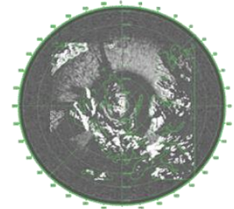
Wake losses – energy yield



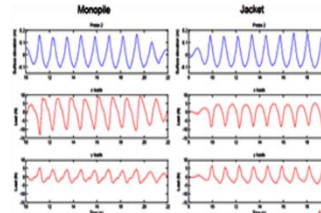
Power control and loading



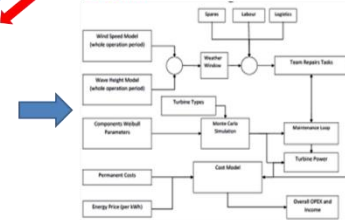
Radar scattering



Loading and materials



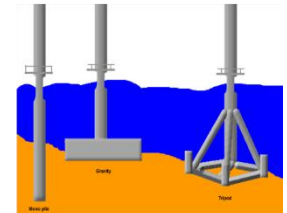
O & M



Connection



Foundations



Output Metrics

**Cost of energy,
Availability
Etc...**



Our highlights

- Innovative new side-band-based methods
- Earlier detection of emerging faults.
- New blade fatigue dual-axis testing methods
- For the first time, detection of mechanical faults from power signals
- Comprehensive study of UK long term wind variability
- Better modelling and understanding of large array wake losses
- New concepts for HVDC control and DC protection.
- New models for HVDC connections
- State-of-the-art safety critical offshore radar
- New FEM for composite joints in blades.
- New GIS model for assessing economic potential of offshore farms
- More detailed aero-elastic blade model
- State-of-the-art wind farm control analysis and design model.
- Novel hierarchical, decentralised and scalable approach to wind farm control
- First cost benefit analysis including economic, emissions and 'green jobs' impact
- First UK dynamic, energy-economy-environment computable general equilibrium model
- Prediction methods for novel foundation installation requirements





Funding: Our Grand Challenges (£3M)



- MAXFARM (MAXimizing wind Farm Aerodynamic Resource via advanced Modelling): Led by Dr Phil Hancock, Surrey
- Maximising the Carbon Impact of Wind Power: Led by Professor Richard Green, ICL
- Screw piles for wind energy foundation systems: Led by Dr Mike Brown, Dundee
- Servo-aeroelastic tailoring of wind turbines using new active-to-passive control systems: Led by Professor Paul Weaver, Bristol



Funding: Flexible Funding

TOTAL AWARDED: £1,257,816

- **Round 1 Call (Dec 2015 – wind energy):**
£280,029 awarded: Cranfield, Oxford, Strathclyde)
- **Round 2 Call (Jun 2016 - relating to OREC Levenmouth test turbine)**
£319,251 awarded: Durham, Manchester/Glasgow/UCL,
Strathclyde/Edinburgh
- **Round 3 Call (April 2017 - health and safety)**
£234,555 awarded: Strathclyde/Exeter, Cranfield
- **Round 4 Call (Aug 2017 - floating wind)**
£199,788 awarded: Cranfield/ICL, Cranfield/Strathclyde
- **Special Projects Call (May 2018 – developing current activities)**
£224,193 awarded to 8 individual special projects





Funding

- 2014-2019 (Phase 3), £3M for core operations
- £1.2M spent on Flexible/reactive funding throughout the project
- ORACLES flexible funding project 1 March 2018 – 28 February 2019

10:30-11:00

'Offshore Renewables Accessibility for Crew Transfer, Loss Estimation and Safety (ORACLES)'

Dr David McMillan, University of Strathclyde





Industry focus

- **The hub and specific projects were built with strong industrial partnerships**
- **Research in an International and UK context**
- **Industry setting the research agenda**

11:00-11:30	University of Dundee led industry session <i>'Decommissioning Offshore Wind – lessons learned from the O&G industry'</i> Clare Lavelle, Arup
11:30-11:45	Coffee and refreshment break
11:45-12:15	<i>'Hywind Project – Status and future challenges'</i> Bjørn Johansen, Equinor
12:15-12:45	<i>'Foundation Design for the Beatrice Offshore Wind Farm'</i> Robert McLean, Atkins Global



The future: UK/China ORE projects

- 2017 £4M UK & 3M RMB for joint research (EPSRC, Newton, NERC, NSFC)
- Tackling key technology and engineering challenges
- Integrated consideration of environmental science
- Resource characterisation, Resilience against extreme events, High efficiency, Integrated offshore natural resource systems

12:45-13:45	Lunch and poster session
13:45-15:15	UK/China ORE Session <i>'Extreme wind and wave loads on the next generation of offshore wind turbines'</i> Professor Tom Adcock, University of Oxford <i>'FENGBO-WIND: Farming the Environment into the Grid: Big data in Offshore Wind'</i> Professor Mike Graham, Imperial College London <i>'Resilient Integrated-Coupled FOW platform design methodology (ResIn)'</i> Professor Lars Johanning, University of Exeter
15:15-15:30	Coffee and refreshment break



The future of UK ORE Research

- In 2019 the Supergen Wind Hub funding period will end
- The future of ORE research is the new EPSRC ORE Hub with £5M
- Brings together Wind, Wave and Tidal research

15:15-15:30	Coffee and refreshment break
15:30-16:20	<p>Supergen ORE Hub session</p> <p><i>'Ecologically sustainable futures for large scale renewables and how to get there'</i> Professor Beth Scott, University of Aberdeen</p> <p><i>'EPSRC Offshore Renewable Energy Hub'</i> Dr Tim Stallard, University of Manchester</p>

ORE Supergen



Offshore Renewable Energy

ORE Supergen Directors





Poster session

12:45-13:45

Lunch and poster session

University of Dundee
ROGER BULLIVANT
SUPERGEN WIND
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Using DEM to Investigate the effects of Pitch on Screw Piles Installation

Y. Sharif, M. Gantia, C. Davidson, T. Al-Bagdadi, M. Brown, J. Knappett, A. Brennan, J. Ball

1. Introduction

Screw piles have been proposed as an alternative foundation solution for offshore wind turbine foundations in deeper waters (>40m) alongside jacket structures (Fig. 1)

Using numerical and physical modelling, the Universities of Dundee (UoD) plus an industrial partner are developing techniques to investigate the effects of geometry on the installation requirements of screw piles in sand.

Screw piles have a hollow core with a single or multiple helical plates (Fig. 2) and are installed by applying torque and vertical force.

Benefits of screw piles include:

- High axial capacity
- Low noise and vibration pollution
- Potential cost reduction with efficient use of material and quick installation time

Challenges:

- Upscaling current offshore designs
- Uncertainty surrounding behaviour under cyclic loading
- Predicting installation torque and force
- Existing analytical¹ and empirical² methods may not be correct
- Existing CPT (Cone Penetration Test) correlation methods^{3,4} do not take into account all geometric properties
- Effects of some geometric and installation properties such as pitch are still unknown

Through the use of the Discrete Element Method (DEM) calibrated through triaxial element tests and centrifuge model tests a method has been developed to investigate the effects of geometry on the installation torque and force.

2. DEM modelling

Using PFC3.0⁵ a series of virtual centrifuge tests were created in which 1/50th scale straight shafted piles and screw piles were installed into dense dry sand at an equivalent of 50g acceleration in a geotechnical centrifuge. The model was calibrated against triaxial element tests⁶ and physical geotechnical centrifuge tests⁷ conducted at the University of Dundee.

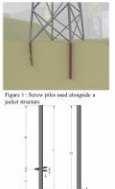


Figure 1: Example of a single pile being installed in sand.

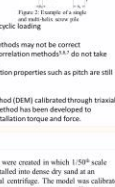


Figure 2: Example of a screw pile with multiple helical plates.

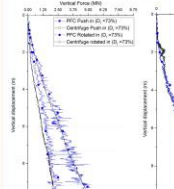


Figure 3: Example of a screw pile being installed into sand at 50g in a CPT.

3. Model Calibration

Model calibration was undertaken using results of straight shafted piles installed by axial jacking and rotary jacking conducted in the geotechnical centrifuge at the University of Dundee (Fig. 5).

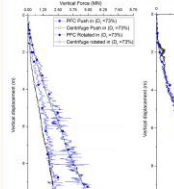


Figure 4: Calibration of vertical force (kN) and torque (kNm) DEM model using centrifuge data for axially jacked and rotary jacked straight shafted piles.

4. Future Work

- Confirm particle scaling in sample produces correct soil response
- Conduct DEM analysis for straight shafted piles installed at various pitches in three different soil densities
- Complete centrifuge tests to confirm results of DEM models of straight shafted piles
- Conduct DEM analysis on screw piles with different pitches in three different soil densities

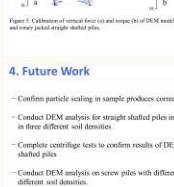


Figure 5: Calibration of vertical force (kN) and torque (kNm) DEM model using centrifuge data for axially jacked and rotary jacked straight shafted piles.

5. Acknowledgements

The authors would like to thank the following organisations for their support: SUPERGEN WIND, EPSRC, the University of Dundee, and the University of Southampton.

6. References

1. Gantia, M., Sharif, Y., Al-Bagdadi, T., Brennan, A., Knappett, J., Ball, J., & Bullivant, R. (2015). A novel foundation solution for offshore wind turbines in deep water. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering and Technology Design*, *219*, 1-10.
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7. Gantia, M., Sharif, Y., Al-Bagdadi, T., Brennan, A., Knappett, J., Ball, J., & Bullivant, R. (2015). A novel foundation solution for offshore wind turbines in deep water. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering and Technology Design*, *219*, 1-10.

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A modified CPT based installation torque prediction for large screw piles in sand

C. Davidson¹, T. Al-Bagdadi¹, M. Brown¹, A. Brennan¹, J. Knappett¹, C. Agard², W. Combs¹, L. Wang¹, G. Richards¹, A. Blake¹, J. Ball¹

1. Introduction

For offshore wind energy to move into deeper water (>40m), alternative foundation solutions are needed (Fig. 1) which overcome issues with manufacturing and installing existing monopile and straight shafted pile systems³.

Using physical, numerical modelling and field testing, the Universities of Dundee (UoD), Durham (DU) and Southampton (SO) plus industrial partners are developing screw pile technology which could address these concerns.

Screw (helical) piles have a tubular core (shaft) with one to several helical plates and are installed with continuous torque and vertical force.

Benefits of screw piles include:

- Quick installation
- Low vibration/low noise
- Efficient material use, generating higher axial capacity through soil-soil shearing when helices are optimally spaced (Fig. 2)

Challenges:

- Upscaling current offshore designs
- Optimising geometry (e.g. core diameter and number, position, size of helices) for typical offshore loads
- Uncertainty over performance under cyclic loading⁴
- Predicting installation torque and force
- Existing analytical¹ and empirical² methods may be unreliable
- In situ CPT (Cone Penetration Test) correlation methods^{3,4} appear more suitable

Through centrifuge modelling of screw piles, the proposed CPT torque correlation updates the previously developed formula⁵ to provide accurate predictions of installation torque.

2. Physical Modelling

Two 1/50th scale model screw piles (Fig. 2) were installed into dense, dry sand at 50g acceleration in the centrifuge at the University of Dundee with a specially developed installation rig⁶.

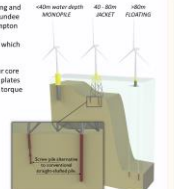


Figure 1: Offshore and foundation solutions.

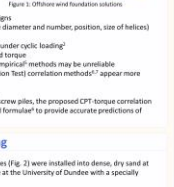


Figure 2: Model screw piles used in centrifuge tests at 50g acceleration in the centrifuge.

3. CPT-Torque Correlation

Principle torque resistances on a screw pile act on the shaft (T_s), base of pile (T_b) and the lower surface (T_{ls}), outer circumference (T_{oc}) and leading edge (T_{le}) of the helix (Fig. 3). Cone resistance (q_c) data from CPT correlated with installation torque using the proposed relationships shown below.

$$T = T_s + T_b + T_{ls} + T_{oc} + T_{le}$$
$$T_s = T_{oc} + T_{le} + T_{ls}$$
$$T_{oc} = \sum_{i=1}^n n_i \cdot \tan \phi_{c,oi} \cdot n_i \cdot d_i^2 \cdot L_i$$
$$T_{le} = q_c \cdot \tan \phi_{c,le} \cdot \frac{d_{le}^2}{12}$$
$$T_{ls} = n_b \cdot \tan \phi_{c,ls} \cdot \frac{d_{ls}^2}{12}$$
$$T_b = n_b \cdot d_b \cdot \frac{d_b^2}{12}$$
$$T_{oc} = n_b \cdot d_b \cdot \frac{d_b^2}{12}$$
$$T_{le} = n_b \cdot d_b \cdot \frac{d_b^2}{12}$$
$$T_b = \frac{F_c}{\tan \phi_{c,b}}$$
$$T_{oc} = \frac{F_c}{\tan \phi_{c,oc}}$$
$$T_{le} = \frac{F_c}{\tan \phi_{c,le}}$$

Figure 3: Torque resistances on a single helix pile during installation.

Figure 4: Torque resistances on a single helix pile during installation.

Figure 5: Predicted and measured installation torque for centrifuge tests of the single helix (Fig. 2a) and multi-helix (Fig. 2b) are shown in a) and b), while field tests of screw piles reported in c) and d) are shown in e) and f) respectively.

4. Acknowledgements

The authors would like to thank the following organisations for their support: SUPERGEN WIND, EPSRC, the University of Dundee, and the University of Southampton.

5. References

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