Supergen

Offshore Renewable Energy

Early Career Researcher Posters and Abstracts Booklet

2025 Annual Assembly

Surnames A - L

Engineering and Physical Sciences Research Council

Supergen Offshore Renewable Energy

Early Career Researcher Posters 2025

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Yabin Liu, University of Cambridge Controlling Tip Vortices with a Grooved-tip Design
Chenying Liu, University of Oxford Origami-Enhanced Dielectric Fluid Generator for Wave Energy Conversion

Abel Arredondo-Galeana, University of Strathclyde

Job Title: Research Associate

Academic Discipline: Marine Renewables

We propose a hybrid wind and wave floating platform to provide a continuous minimum power base load for offshore applications. The platform consists of three pontoons interconnected with mechanical hinges. A single point mooring line allows passive yaw of the platform. A 5 MW wind turbine is installed on deck and downstream of the platform. Wave energy is extracted through hinge motion, and a potential flow numerical model is used to derive the power matrix for the wave energy conversion system. The role of the wind and wave correlation indices, and wind and wave power densities in the performance of the platform are investigated in three locations with different characteristics. One in the Coast of Spain, which is swell dominated, and two off the coast of Scotland, one in the west and one in the east. By considering a minimum power threshold of 100 kW as the criterion at which power is produced, short term and long term metocean data are fed in into the wind turbine power curve and power matrix of the platform. It is found that the hybrid platform reduces the wind power downtime in the three locations, with the highest drop in power at the site with lowest wind and wave correlation, showing a drop in power from 7% to 3.5%. Furthermore, we find that wind power density determines the initial power downtime in the three locations when only the wind turbine operates, while wave power density determines the level at which the power downtime drops in the three locations when wind and wave energy are extracted. Hence, this work suggests that locations with high wave power density and low wind and wave correlation indices, are the most ideal to deploy hybrid wind and wave platforms as the one developed in this study.

A hybrid wind and wave floating platform to provide a minimum power baseload for offshore applications.

Dr Abel Arredondo-Galeana[a], Dr Gabriel Scarlett[b], Professor Maurizio Collu[a], Professor Feargal Brennan[a]

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Hybrid platform

In this work, we propose a hybrid wind and wave floating platform to provide a continuous minimum power base load for offshore applications. The platform consists of three pontoons interconnected with mechanical hinges. A single point mooring line attached to the bow of the platform allows passive yaw. A 5 MW wind turbine is installed downstream of the platform and wave energy is extracted at the hinges. The floating concept is illustrated in Figure 1, where the NREL 5 MW wind turbines is utilised. Each pontoon has a 58 x 58 x 1 m dimensions and is designed to provide sufficient buoyancy to carry the mass of the turbine and additional ballasting materials.

a)

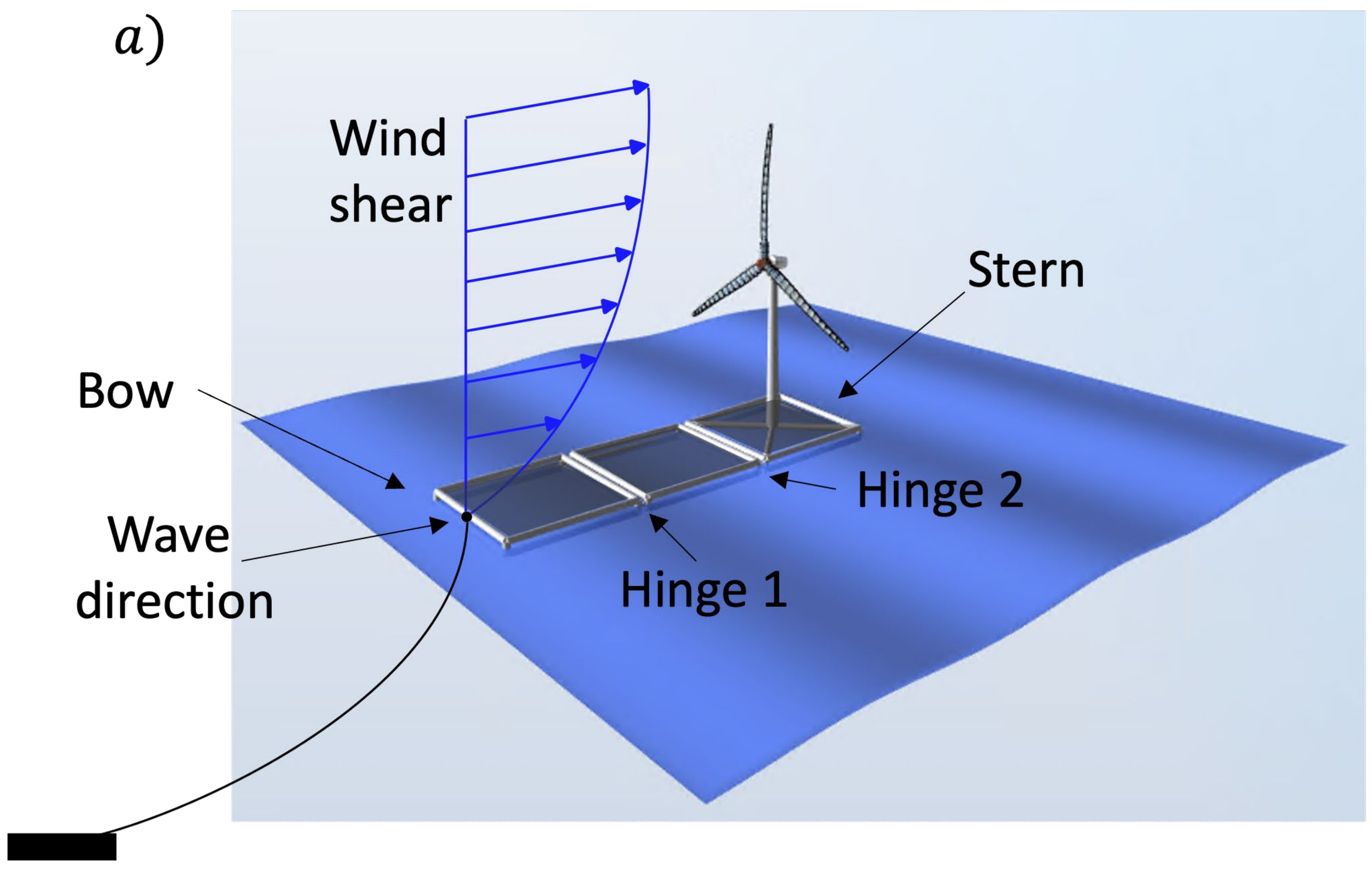

Figure 1– Hinged very large floating structure (VLFS) with 5MW NREL wind turbine

The performance of the hybrid platform is studied in three different locations with different wind and wave characteristics. One in the Coast of Spain (VS), which is a low wind and wave correlation site, and two off the coast of Scotland, one in the west (NE3) and one in the east (NE8). The locations around Scotland are selected because they have higher wind and wave correlation indices. The role of the wind and wave correlation index and power density in the performance of the hybrid platform are investigated.

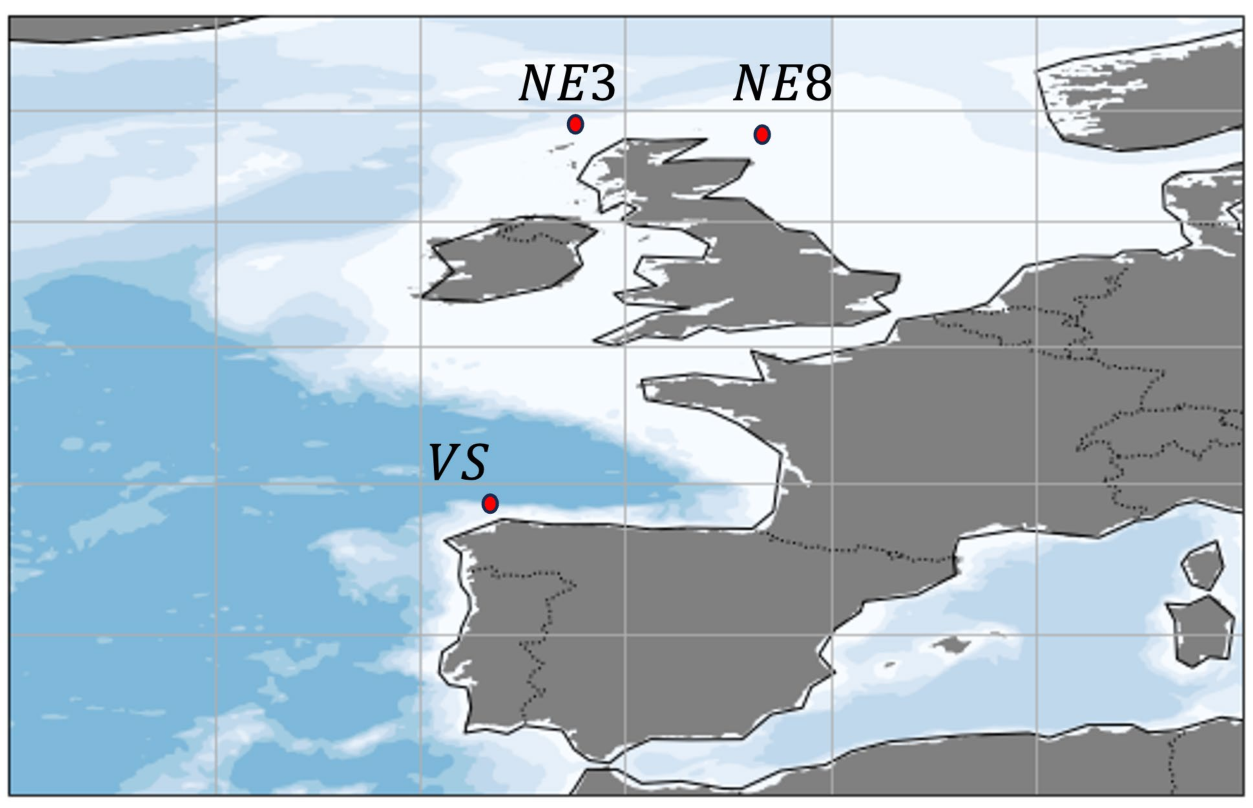

Figure 2– Locations selected to analyse the performance of the hybrid platform

Power performance

For wind turbine power performance, we utilise the average 5MW NREL power curve, due to small pitching angle motions of the downstream pontoon. For wave power performance, we compute the flex angle at the hinge locations with a low order potential flow numerical model. A JONSWAP spectrum is utilised to generate discrete waves that represent a random sea state. Subsequently, a power matrix of the system is computed by combining the response of the two hinges. Results are presented in Figure 3, where the broadband peak response between *10 s < Ts < 12 s* is due to the combined effect of the two hinges of the hybrid platform.

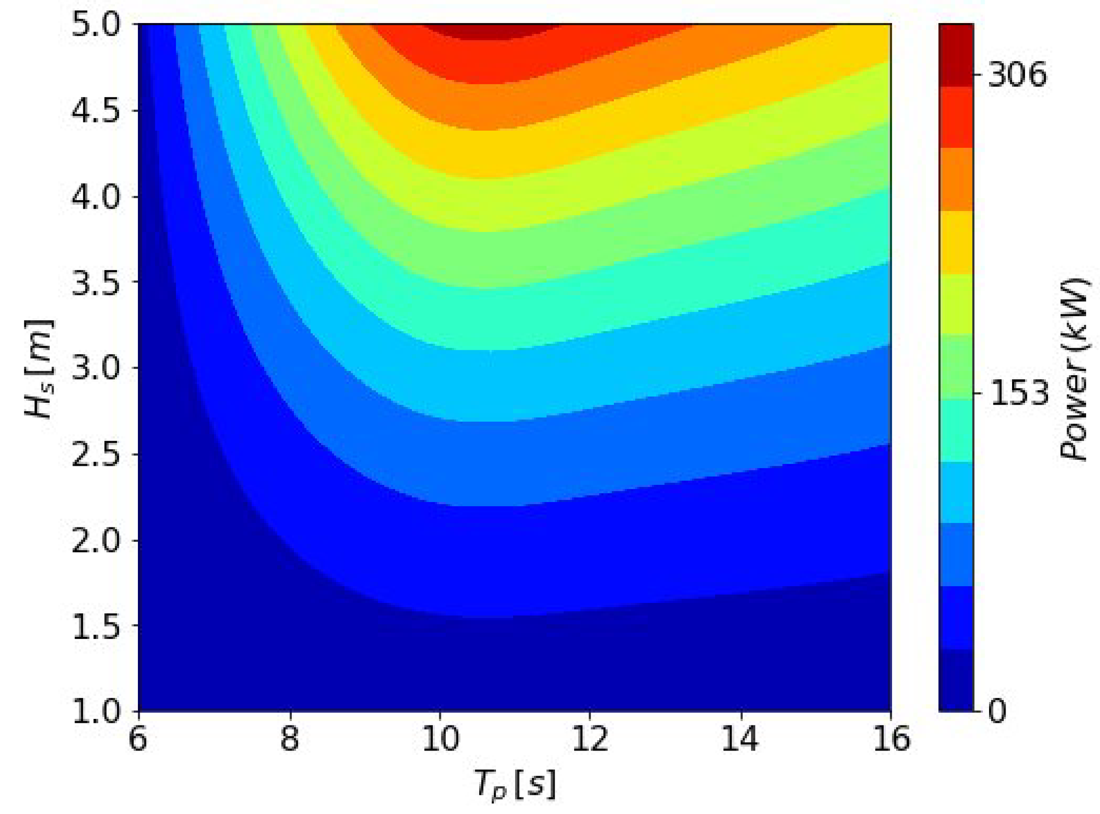

Figure 3 – Power matrix of hinged platform assuming irregular waves

Results

By defining a 100 kW as the wave power threshold at which power is produced, in the absence of wind power, yearly averages in power downtime show a **reduction in power downtime** for the three selected locations, as follows: **8.2% to 3.6%, 6.1% to 3.1% and 4.7% to 4.3% for VS, NE3 and NE3, respectively**. Results are obtained from hourly resolution metocean data during year 2019. The amount of power downtime reduction is inversely proportional to the wind and wave correlation indices of each location. Results are summarised in Table 1.

Location (correlation index)	% Power downtime Wind	% Power downtime Hybrid
VS (low)	8.2%	3.6%
NE3 (med)	6.1%	3.1%
NE8 (high)	4.7%	4.3%

Table 1– Power downtime considering only wind and hybrid power generation.

Note that highest drop in power downtime occurs in the location with the lowest wind and wave correlation index.

Long term analysis

By utilising 20 years of metocean data (2000-2019) and the same wave power threshold as in Table 1 (100 kW), it is confirmed that the hybrid platform reduces the wind power downtime in the three locations. Specifically, it is found that the drop in power downtime is the highest in locations with the lowest wind and wave correlation index, showing a drop from 7% to 3.5% power downtime. The left bars of Figure 5a show that wind power density determines the initial power downtime in the three locations when only the wind turbine operates (Left columns of Figure 5b). In contrast, the middle columns of Figure 4a, wave power density, determine the level at which the power downtime drops in the three locations when hybrid energy is extracted (Right columns of Figure 5b). . Hence, this work suggests that locations with high wave power density and low wind and wave correlation indices, are the most ideal to deploy hybrid wind and wave platforms as the one developed in this study.

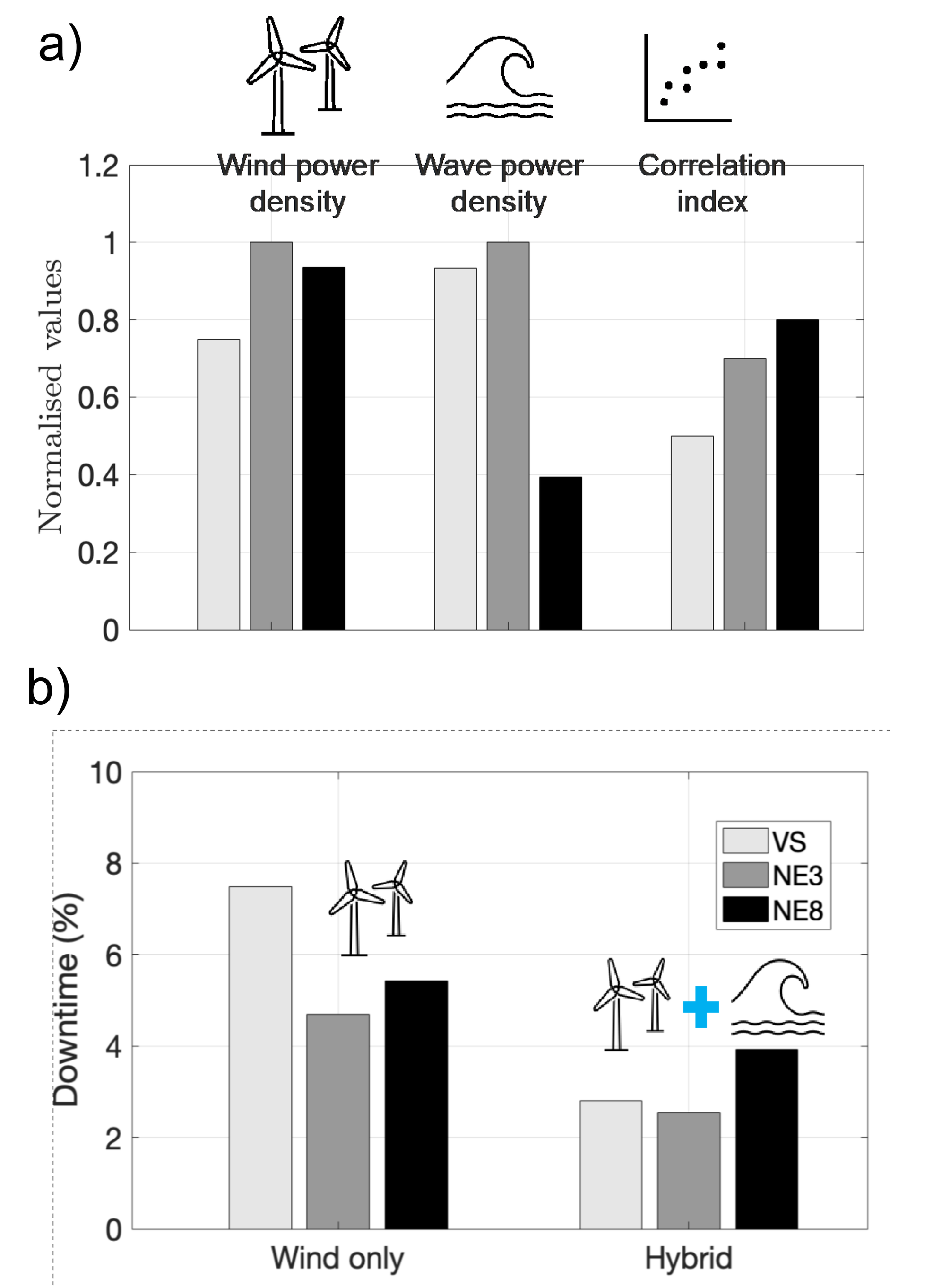

Figure 5– a) Wind, wave power density, and correlation indices of VS, NE3 and NE8, b) power downtime due to wind and hybrid platform during 2000-2019

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University of Strathclyde
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Abigail Bateman, University of Southampton

Job Title: Senior Research Assistant

Academic Discipline: Geotechnical Engineering

Enhanced site investigation methods are crucial to meet the UK 50GW offshore wind capacity target by 2030. The ROBOCONE p-y module is a new site investigation tool that mimics the displacement of a laterally loaded pile by moving part of the module horizontally in order to directly obtain lateral load-displacement curves. This enables direct, relevant in-situ testing with no soil sampling required and the application of complex (cyclic) loading. The module can be included behind a standard CPT cone. However, interpretative methods are needed to obtain soil properties or simulate p-y curves. Existing methods employ a similarity approach to linearly scale the load-displacement curve from the ROBOCONE to predict a p-y curve applicable to a specific pile. However, limited validation of this approach exists and is complex to undertake in soil that is inherently non-linear. In this work, the similarity approach is investigated by testing the p-y module in a calibration chamber with an elastic foam material. Similarity factors obtained using theoretical calculations are used to predict the elastic properties of the foam material, which are estimated to be within 10%. Finally, an initial approach to develop a p-y curve from the ROBOCONE module is demonstrated.

Using elastic foam tests to investigate an interpretation method of the ROCOCONE p-y module

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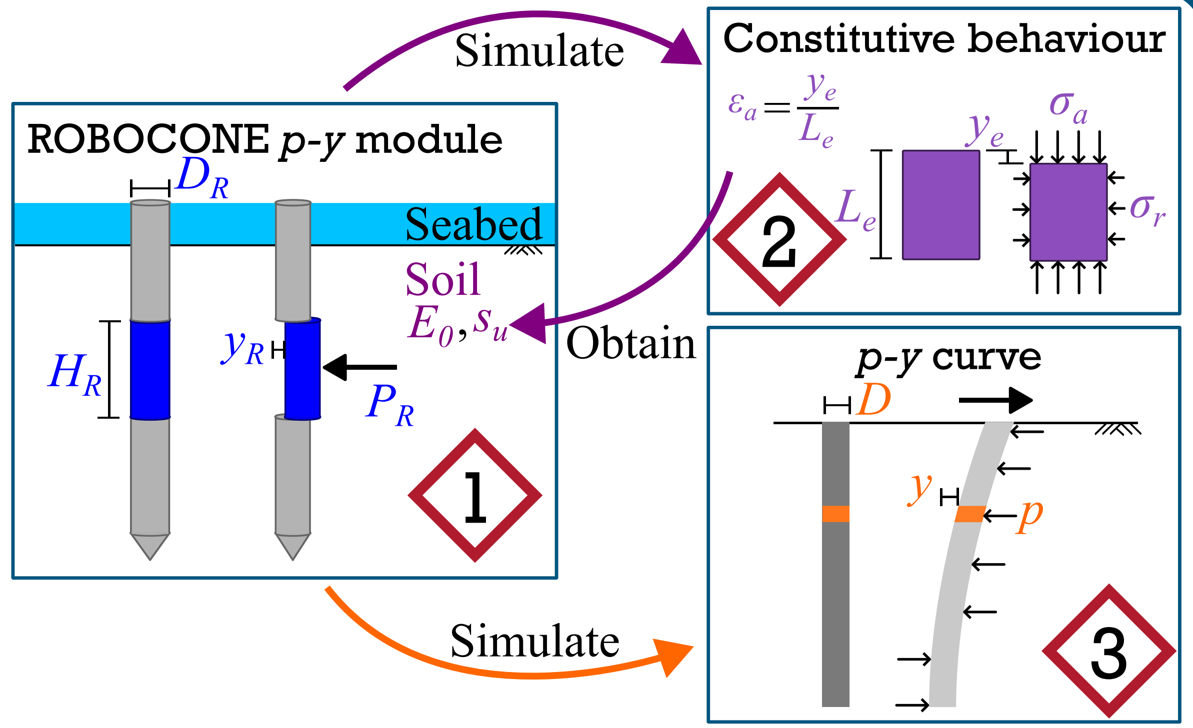

Fig 1. Schematic of the ROBOCONE p-y module to obtain soil properties and simulate p-y curves

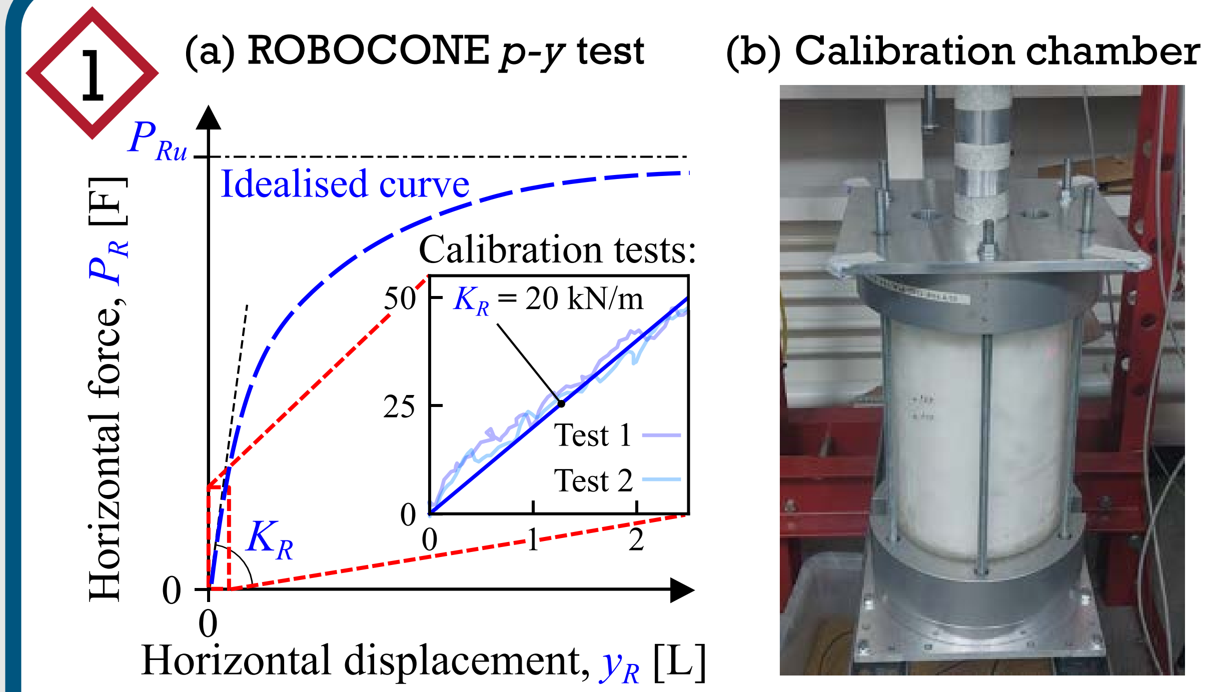

Fig 2. Idealised load-displacement curve of the ROBOCONE *p-y* module and measured response of elastic foam in (b) the calibration chamber

Scott Brown, University of Plymouth

Job Title: Supergen ORE Hub Research Fellow

Academic Discipline: Engineering

Governments around the world are increasingly focusing on the development of offshore renewable energy (ORE) as a key component of their sustainable energy strategies. As a result, there has been a surge in investment and research aimed at harnessing the vast potential of offshore resources, including wind, wave, and tidal energy. One of the major challenges in designing floating ORE devices is the limited data and understanding of their response to extreme events. Accurately predicting the ultimate loads that these structures will experience is crucial for ensuring their safety and reliability, as well as for instilling investor confidence and maintaining cost-competitiveness. Traditional design standards, however, often rely on computationally intensive methodologies that require simulating large quantities of data based on short-term irregular sea states. This makes them mostly applicable to scenarios where linear responses can be assumed, and they become impractical when high-fidelity modelling is required.

Researchers have introduced the concept of "short design waves" to address the challenges associated with modelling extreme conditions for offshore renewable energy (ORE) devices. This approach involves simulating specific wave profiles that are likely to induce extreme structural responses, thereby circumventing the need for long-duration irregular sea state simulations. The shorter time scale of these waves enables the application of high-fidelity numerical modelling, offering a promising alternative to traditional engineering models (typically used outside their range of validity) or resource-intensive laboratory experiments, particularly for design load cases which assess survivability in extreme conditions. Furthermore, high-fidelity modelling provides enhanced control over mass properties and inflow conditions compared to physical experiments, while also avoiding the scaling restrictions that often constrain physical modelling. Therefore, the present study focuses on the development of high-fidelity numerical models for floating ORE structures, integrating short design wave techniques to refine and optimise the design process.

Development of High-Fidelity Models for Extreme Loading Events on ORE Devices

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Aims and Objectives

- Develop high-fidelity numerical tools in OpenFOAM to assess the survivability of floating offshore renewable energy (ORE) devices.
- Integrate response-conditioned short design wave (SDW) techniques into the models, developed through Supergen ORE Hub, for more efficient ultimate load estimation.

Design Waves and High-Fidelity Modelling

- SDW techniques efficiently predict ultimate loads for given metocean conditions.
- Unlike traditional 3-hr irregular sea states, SDWs are typically short wave groups that target extreme events.
- Response-conditioned methods are being developed through Supergen, using the response RAOs.
- The short duration of SDWs enables high-fidelity simulations of extreme responses to be more practical.
- This makes computational fluid dynamics (CFD) a more viable tool in the design process for floating ORE devices.

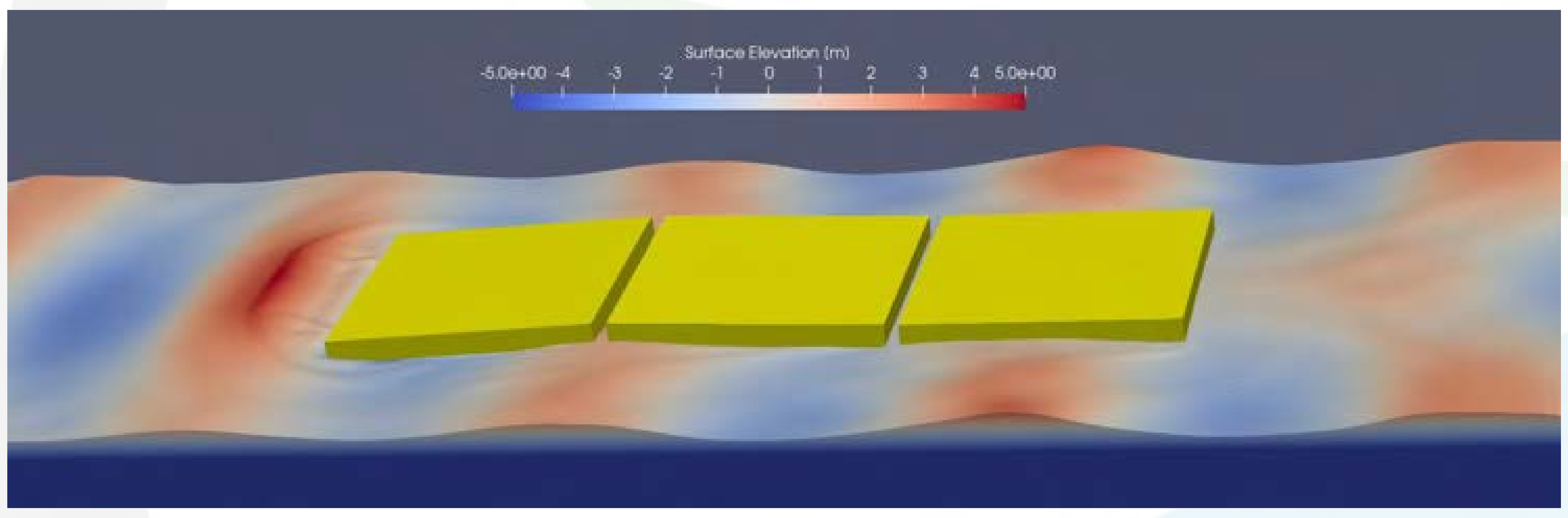
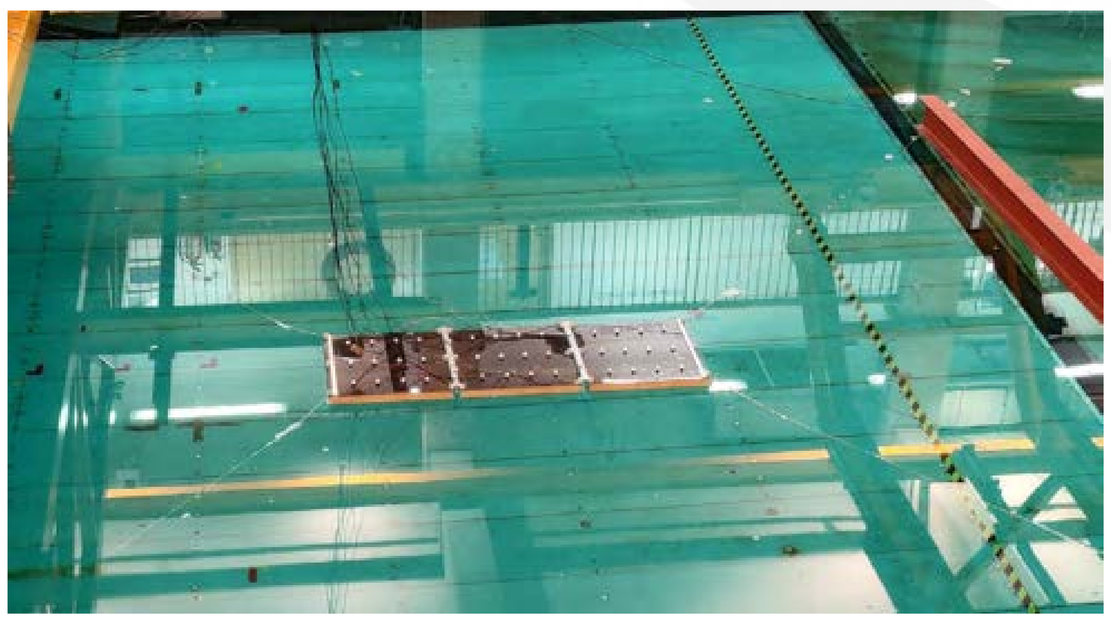


Figure 1: *CFD model of the VLFS. The model is being validated against regular wave data collected in the COAST Lab.*

Very Large Floating Structures (VLFS)

- Developed a numerical model of a floating VLFS, the basis of a hybrid wind-wave platform being considered in Supergen[1].
- The platform consists of three interconnected pontoons with mechanical hinges.
- A potential flow model was developed to estimate the motion of the platform in regular and irregular wave loading.
- A three-way validation between experiments, high fidelity and low order numerical approaches is currently under way.
- The CFD model enables assessment of green water impact, extreme hinge/mooring loads, and pressure distributions.



University of Strathclyde Glasgow

Figure 2: *Physical model of the VLFS being tested in the COAST Laboratory.*

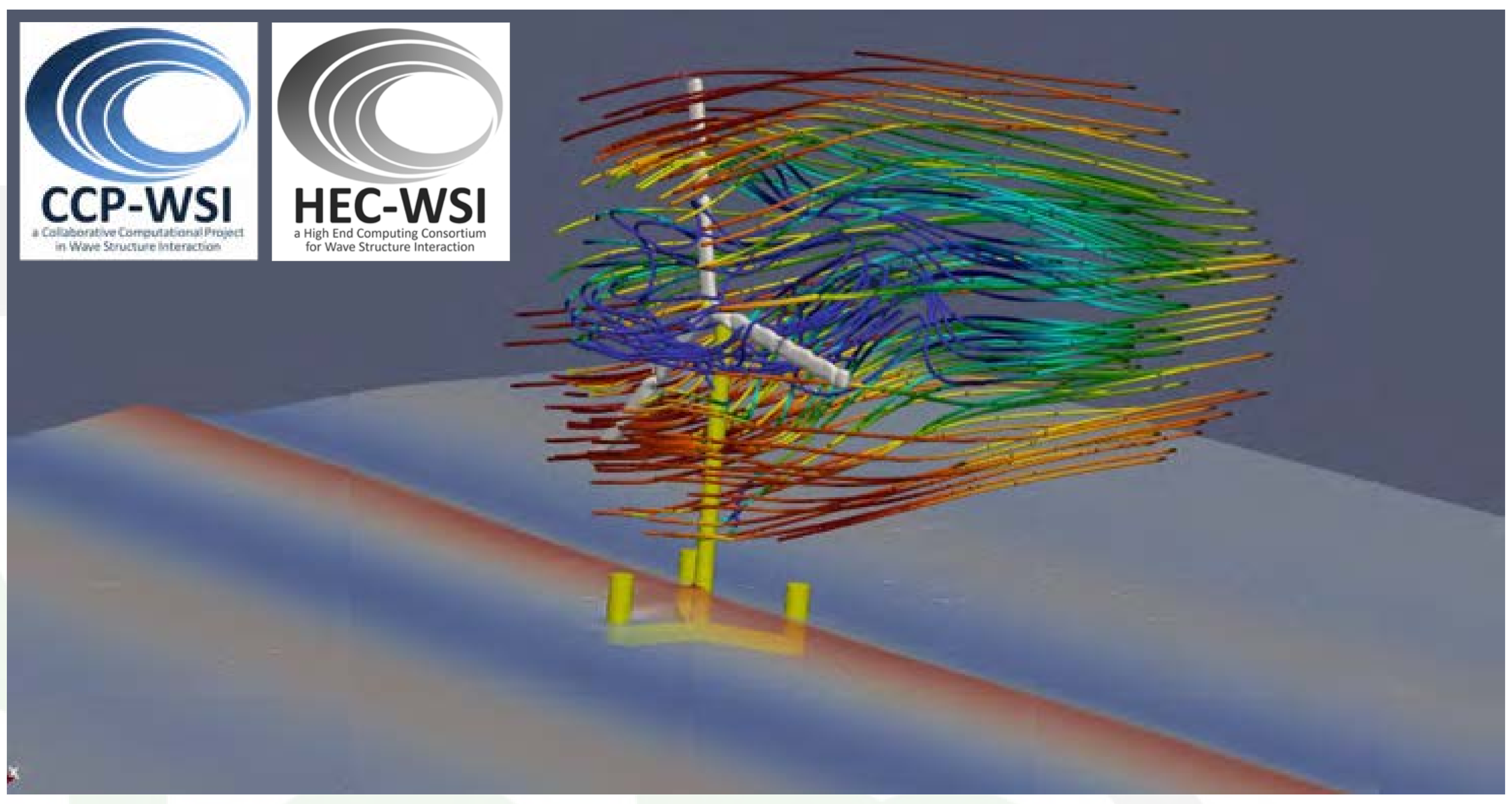


Figure 3: *CFD model of a pitch response-conditioned SDW (most likely extreme response) interaction with a FOWT.*

Floating Offshore Wind

- Developing a numerical replica (Fig. 3) of the COAST Lab's 1:70 scale VolturnUS-S (Fig. 4).
- The model enables:
  - Insight on fluid flow.
  - Increased flexibility to vary device characteristics.
  - Expansion of databases on ORE ultimate loads.
  - Consideration of flow-related responses.
- Test case being developed of pitch response-conditioned SDW interactions with a FOWT (Fig. 3).

Figure 4: *Photograph of the COAST Lab's 1:70 scale model of the VolturnUS-S[3].*

Future Work

- Extend the FOWT model to include combined wind-wave short design events, building on a recent Impact Acceleration Project[4].
- Publicly release the FOWT model for broader research and industry use.
- Validate both CFD models against physical modelling data.
- Utilise models to expand databases on ultimate loads for ORE structures[5].

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This work was supported by the Engineering and Physical Research Council (EPSRC) through funding from Supergen ORE Hub [EP/Y016297/1], including an Early Career Researcher (ECR) fund for SB and AAG, and the Collaborative Computational Project in Wave Structure Interaction (CCP-WSI) [EP/T026782/1], including additional bridging funds from the Computational Science Centre for Research Communities. Further support was provided by the High-End Computing Consortium for Wave-Structure Interaction (HEC-WSI) [EP/X035751/1] in the form of computational resource on the UK supercomputing service (Archer2).

Xiaosheng Chen, University of Oxford

Job Title: PDRA

Academic Discipline: Wind and Tidal Energy

Tidal energy is regarded as an important renewable energy source that could contribute to meet net-zero targets. The design and optimisation of tidal stream turbines requires consideration of unsteady flow effects due to strong influence from waves, shear, incoming turbulence, wake interactions etc. Among those, waves are potentially the largest driver of performance and load fluctuations, affecting fatigue life and energy yield. Several studies have analysed tidal rotor performance under the effects of currents and surface waves using both experiments [1-4] and numerical simulation tools like BEM [5] and CFD [6]. Most studies only analyse blade integrated performance metrics such as thrust, power and root bending moments, reporting case dependant fluctuations about mean values from 10% to 200%, while only a few studies investigate loading variations and flow characteristics at local blade sections [6].

The presented study developed a numerical method to simulate the unsteady loading effects and performance variation of our successfully designed and tested lab-scale axial-flow benchmark tidal rotor under regular wave with current. The CFD model combines a stabilised k-ω SST RANS model [7] with an actuator line model (ALM) for rotor blade representation, which is validated in a blind prediction study [8]. The wave is simulated using the OpenFOAM waves2foam package [9], which utilised a Volume of Fluid method and a Generating-Absorbing Boundary Conditions (GABC) [10]. The operation conditions are following the tidal turbine benchmarking experiment, with a regular wave of 0.4 Hz standing frequency and 0.1 m wave-height, under a 1 m/s current.

Acknowledgement

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WaveTide: Wave Effects on a Benchmark Tidal Energy Device

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Introduction

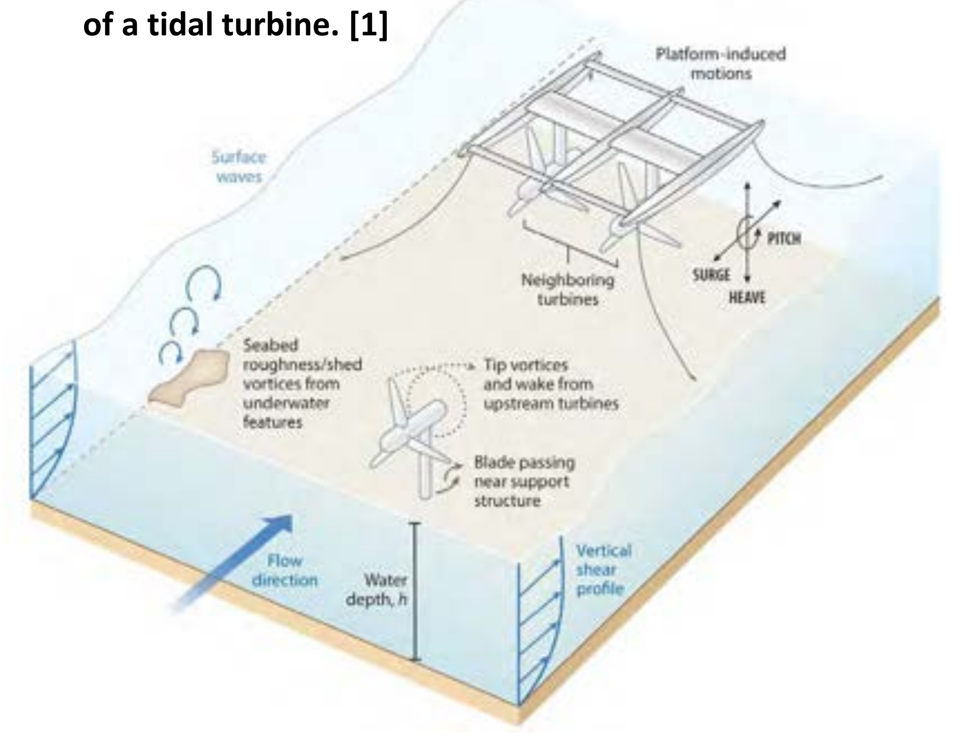
- The tidal turbine benchmark exercise **Stage II experiments with steady wave** has finished in **March 2025**.
- Workshops to be held for the **blind prediction campaign with Stage II measurements** during **summer 2025**, in order to:
  - improve accuracy and confidence of wave-rotor modelling techniques
  - quantify modelling errors for different techniques under different wave scenarios

This project aims to **develop and evaluate** the current CFD modelling technologies for **tidal turbine under waves on a current** through collaboration with research partners, and is published in **AWTEC 2024 Conference**.

This project is funded by the EPSRC SupergenORE HUB EP/S000747/1 ECR research fund, simulations are supported by the HEC-WSI EP/X035751/1 code development fund.

Motivation

The complex flow environment of a tidal turbine. [1]



The **complex flow environment under water** leads to **highly unsteady loadings** on the tidal turbine.

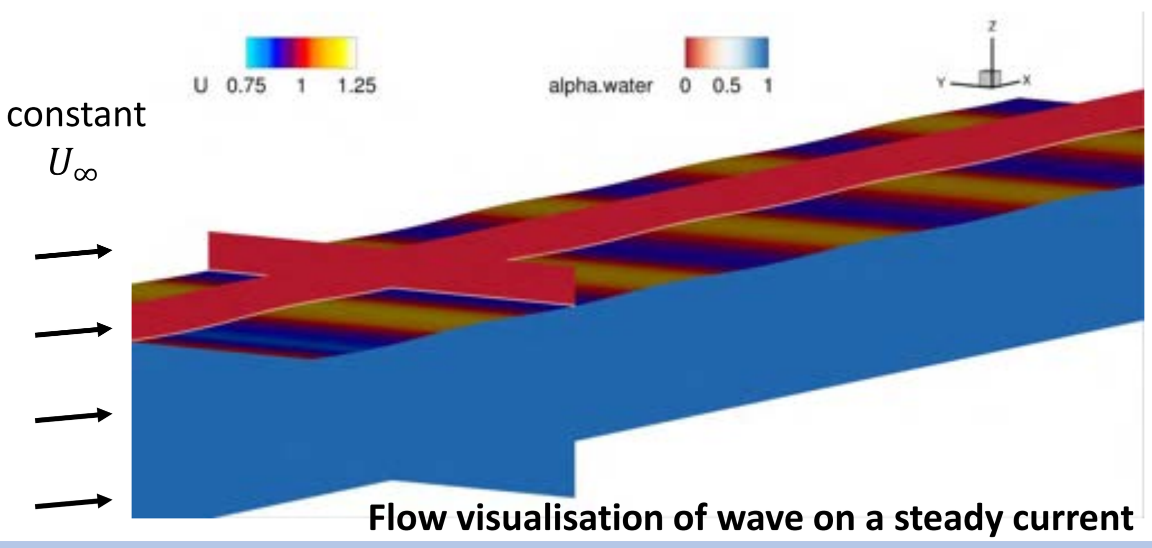
Unsteady loading and the **inability to confidently predict unsteady loading** leads to **huge performance uncertainty** and drives **unnecessary overdesign**, which all contribute to the **high costs in tidal energy**.

One of the **most challenging** aspects for all ORE systems is to design, develop and optimise devices **passively or actively interacting with waves**.

Wave Simulation Method Development & Validation

Simulation Methodologies

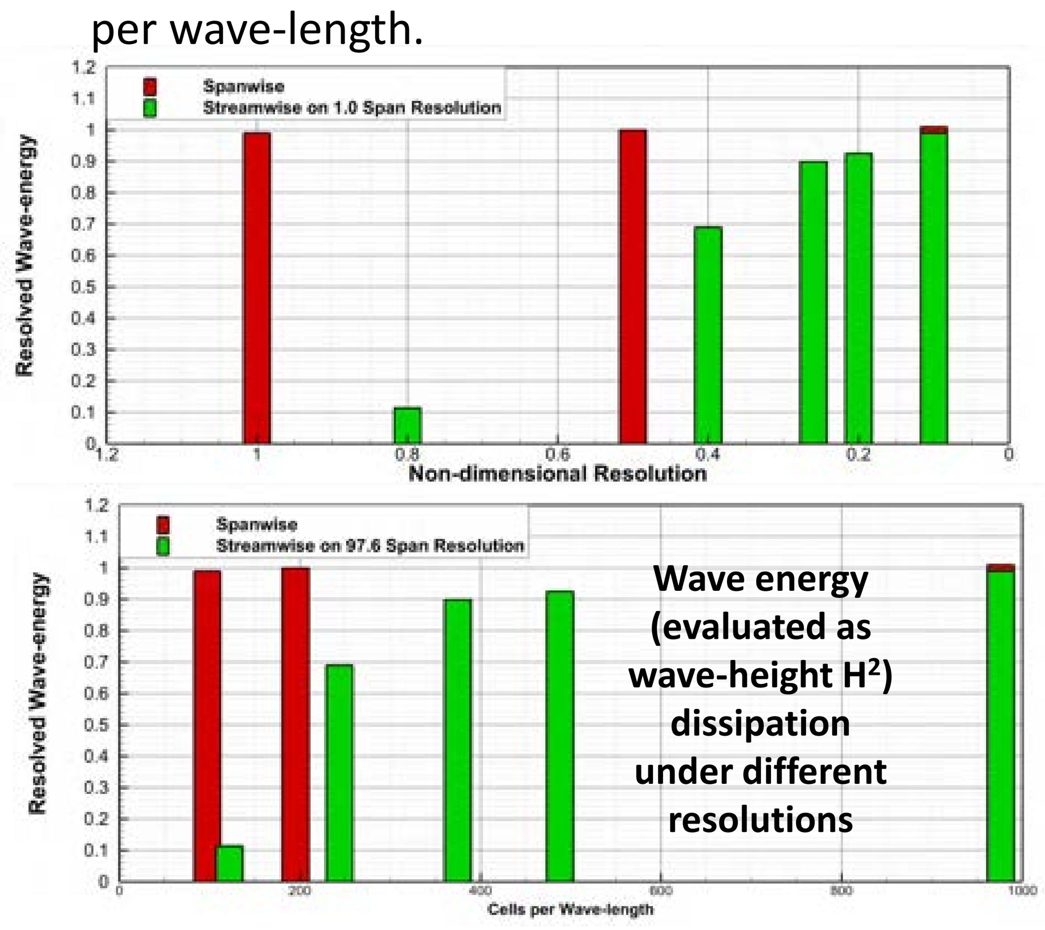
- ❑ Solver tools are using OpenFOAM-v2106, waves2foam [2] and stabRAS_v1712 [3].
- ❑ Water-air interface is modelled by a volume of fluid (VoF) method.
- ❑ Turbulence model is stabilised k-ω SST model.
- ❑ Wave is generated and modelled by the Fenton's stream wave theory and absorbed by the GABC method.
- ❑ Simulation methodologies are utilised in another CFD study on a small-scale experimental scale rotor [4].
- Constant resolution in wave height direction (10 cells per wave-height or 976 cells per wave-length, non-dimensional resolution of 0.1).
- Wave standing frequency of $0.4\,Hz$, encounter frequency of $0.502\,Hz$.



Flow visualisation of wave on a steady current

Wave Energy Grid Dissipation Study

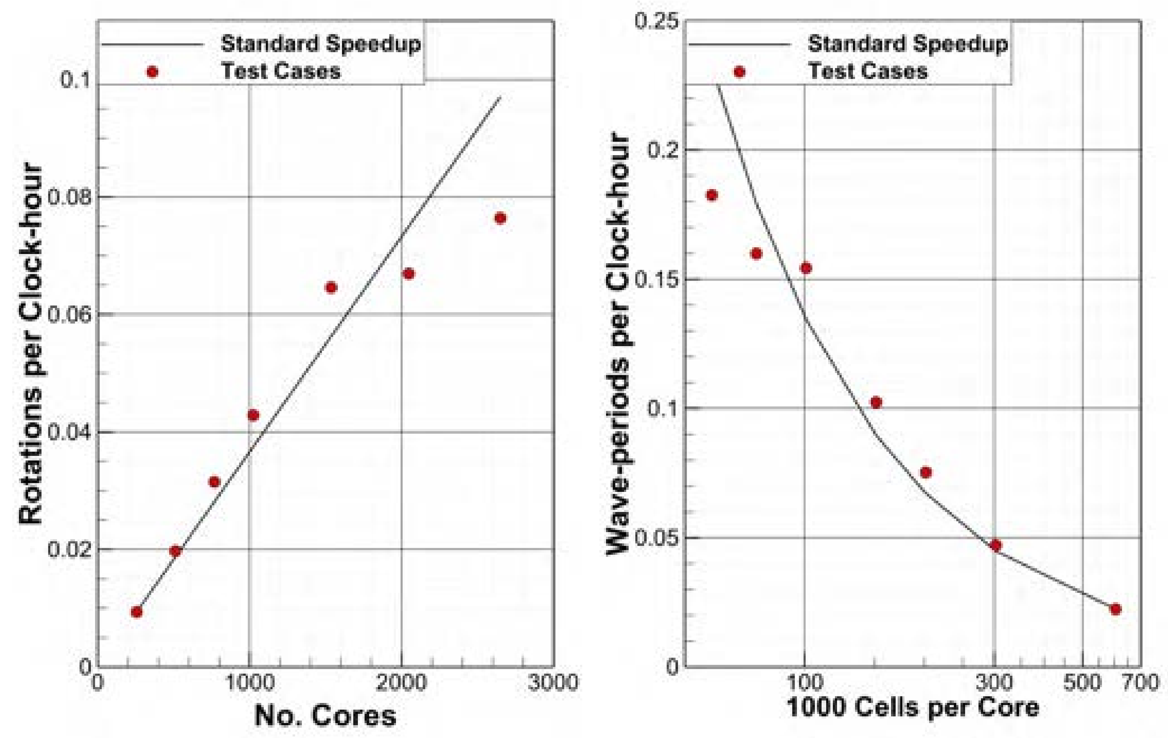
- Different span and stream resolutions studied:
  - Spanwise resolution from 0.1 to 1.0.
  - Streamwise resolution from 0.1 to 0.8.
- Results show that:
  - Spanwise resolution (and cell aspect ratio) influences the stability of the simulation.
  - Streamwise resolution shows close relationship with numerical dissipation in wave energy.
  - 90% of wave energy is maintained with >360 cells per wave-length.



HPC Scaling Tests

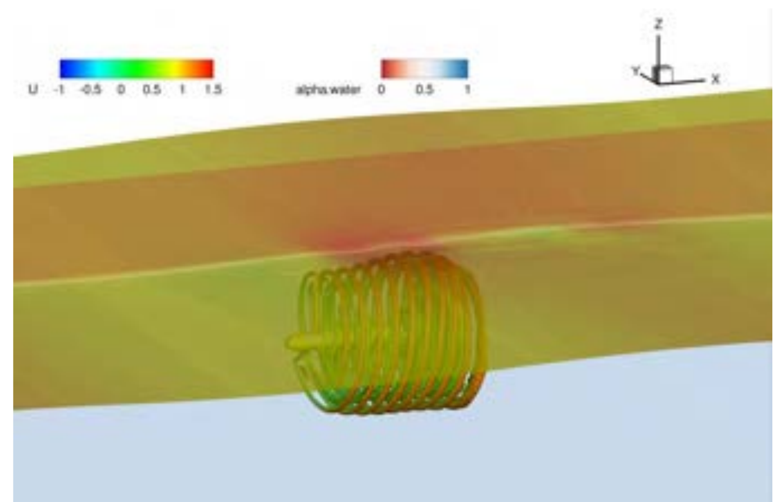
- Based on non-dimensional wave resolution of 1/10, and non-dimensional rotor resolution of 1/160.
- Total cell count 155 million, with 91.6% spent in wave interface, and 8.4% in rotor and wake.
- Scaling test performed on ARCHER2 UK National Supercomputing facility.
- Results shows that:
  - Simulation speed scale well up to 1536 cores (100,000 cells per core).
  - Simulation efficiency drops when <100,000 cells per core.

HPC speed scaling results

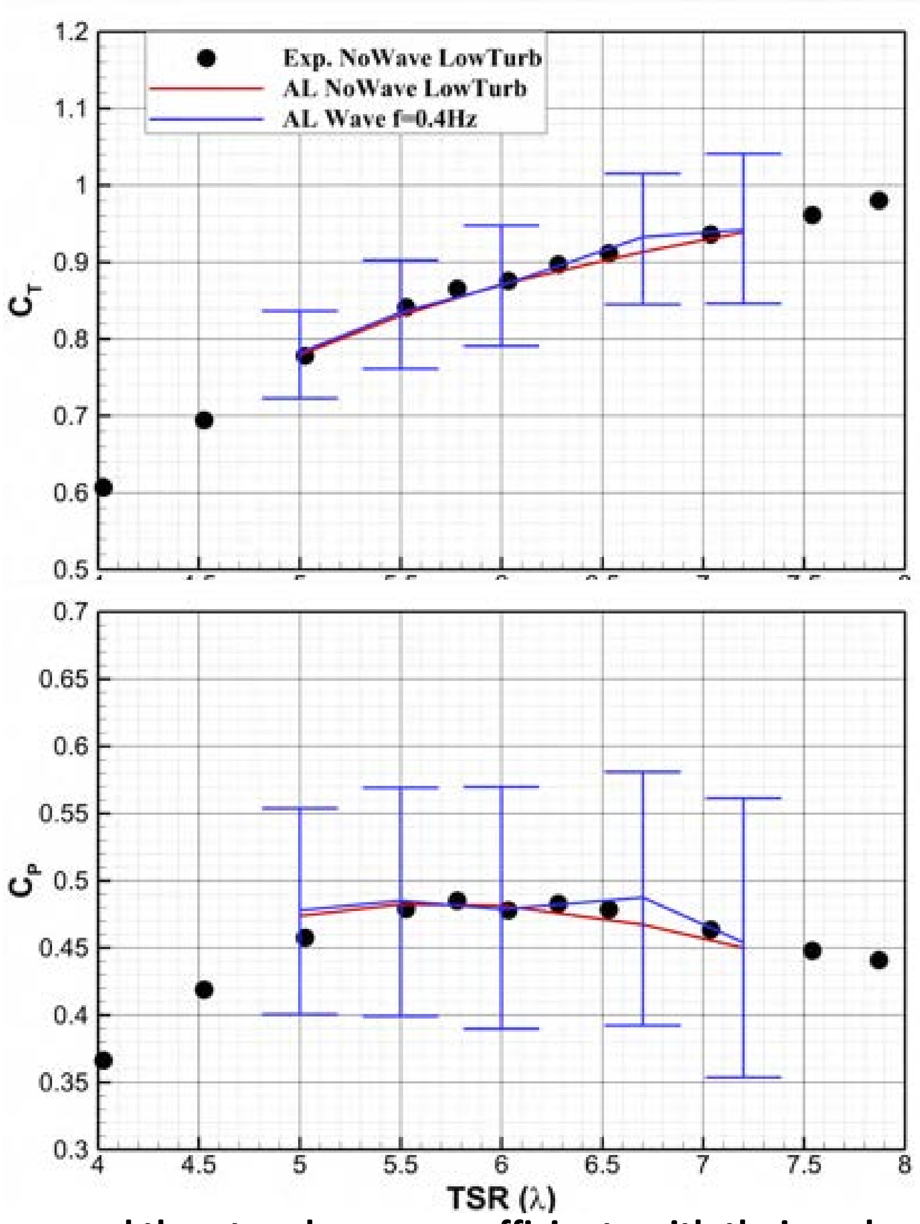


Wave-rotor Interaction Study

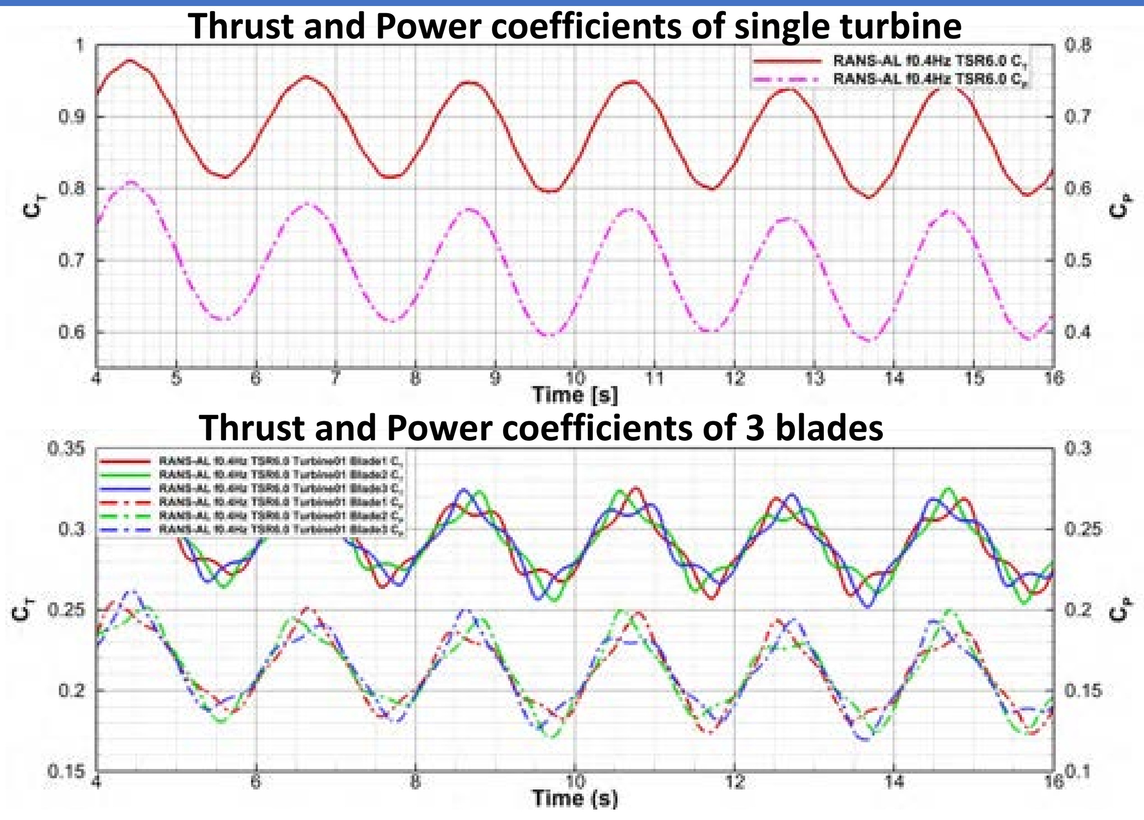
- Configurations [5]:
  - The 1.6m-diameter benchmark tidal turbine.
  - Tip clearance $0.354\,m$.
  - Current $U_\infty = 1.0\,m/s$
  - Wave conditions: frequency $f = 0.4\,Hz$, height $H = 0.10\,m$
  - Turbine operation conditions: $RPM = 72$, $TSR \sim 5.0$ to 7.20
- Experiment and CFD configurations available from https://supergen-ore.net/projects/tidal-turbine-benchmarking



Flow visualisation of the benchmark tidal turbine with wave on steady and uniform current



Time-averaged thrust and power coefficients with their cycle variations



Rotor performance cycle follow **wave encounter periods**, while blade performance cycle shows **mixed frequencies of both wave and rotation**.

Time-averaged rotor performance under wave condition similar to that without wave.

Large fluctuations in performance and blade forces found during wave cycles.

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Jamie Crispin, University of Southampton

Job Title: Lecturer

Academic Discipline: Geotechnical Engineering

Title: Predicting the response of monopile foundations to storm loading from laboratory test data

Abstract: Monopile foundations for offshore wind turbines are subject to significant cyclic loading over their design life. This loading, caused by wind and waves, is highly variable, with loading concentrated in high intensity storm events. Predicting the accumulated rotations and cyclic secant stiffness changes due to these storm events is critical to designing monopiles for serviceability. However, existing modelling approaches are either limited to idealised sinusoidal loading that doesn't accurately reflect realistic load cases or require field test results to calibrate properly, impractically expensive for routine design. An ideal modelling approach would be calibrated with routinely obtained cyclic laboratory testing but allow predictions of the response to realistic storm loading. In this work, two existing models are combined to achieve this.

First, the Simplified UnDrained Cyclic Accumulation Model (UDCAM-S), developed by NGI, is used to calculate the response of a monopile foundation to sinusoidal cyclic loading based on cyclic laboratory test results. However, previously, extension of this model to storm loading would have required idealisation of the load history. Instead, in this work, the Hyperplasticity Accelerated Ratcheting Model (HARM), developed by the University of Oxford, is calibrated directly against the behaviour predicted by UDCAM-S. The UDCAM-S model therefore links HARM to laboratory test data by acting as a substitute for field test data. This novel calibration of HARM therefore allows improved prediction of the monopile response during realistic storm loading from only laboratory test data. The model results are compared with the response predicted using equivalent idealised loading histories directly in UDCAM-S.

Predicting the response of monopile foundations to storm loading from laboratory test data

Supergen Offshore Renewable Energy

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1 Storm loading on monopiles

Wind and waves loading is highly variable, with loading concentrated in high intensity storm events.

Predicting the accumulated rotations and cyclic secant stiffness changes due to these storm events is critical to designing monopiles for serviceability.

An ideal modelling approach would be calibrated with routinely obtained cyclic laboratory testing but allow predictions of the response to realistic storm loading.

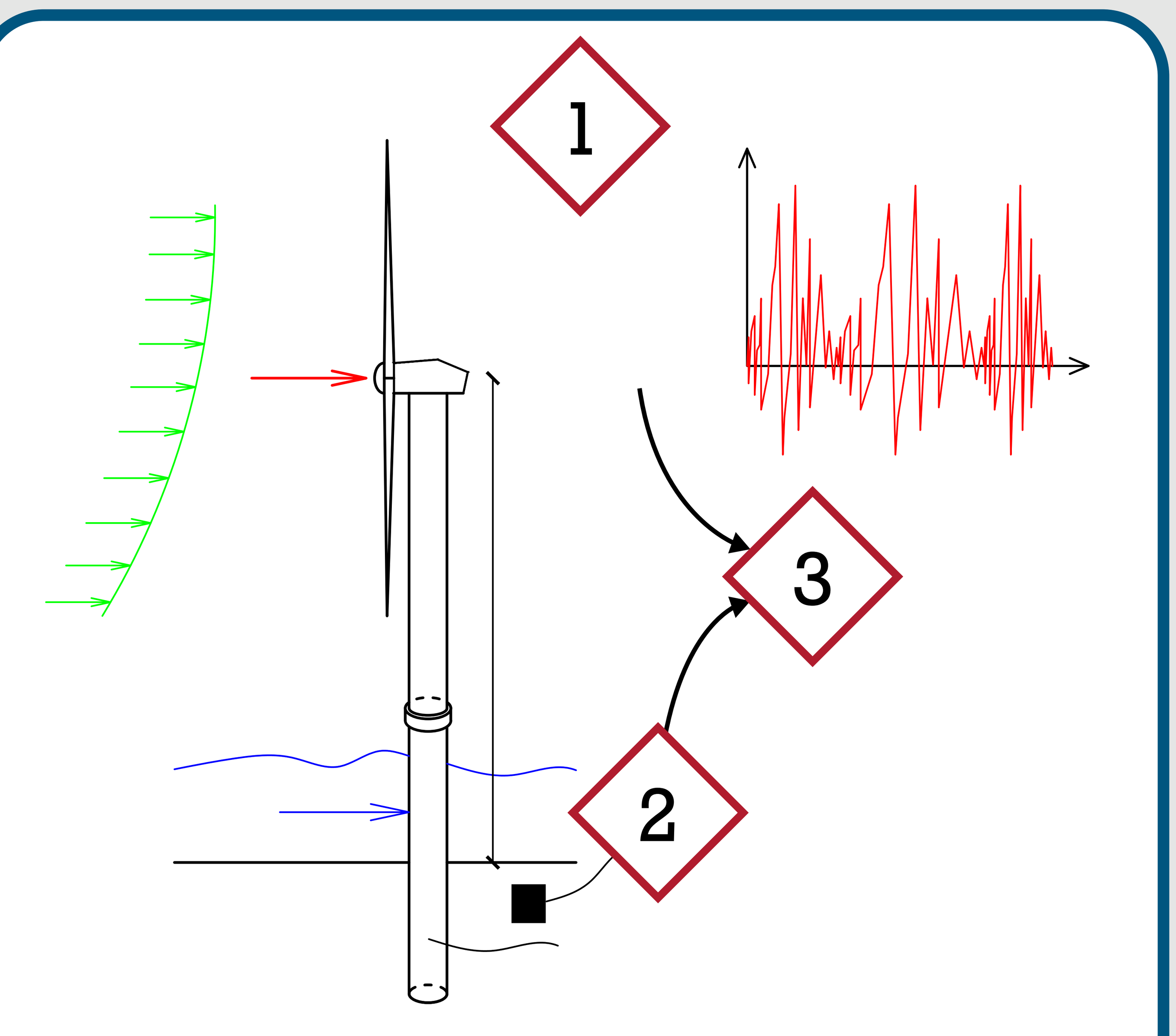


Fig. 1: The problem

2 UDCAM-S

NGI

The Simplified UnDrained Cyclic Accumulation Model (UDCAM-S [1]) was developed at NGI.

Calibrated using routinely obtained cyclic laboratory testing (e.g. DSS), so can be applied to a new material relatively inexpensively through generation of cyclic contour diagrams.

However, UDCAM-S is limited to sinusoidal cycles, so realistic storms must be idealised to packets of increasing amplitude (see Fig. 2).

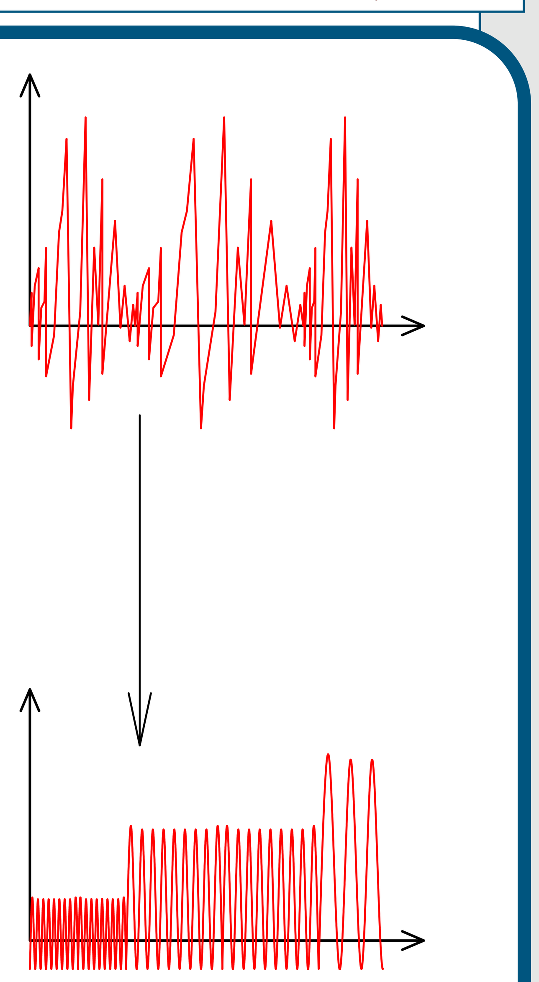


Fig. 2: Idealised loading

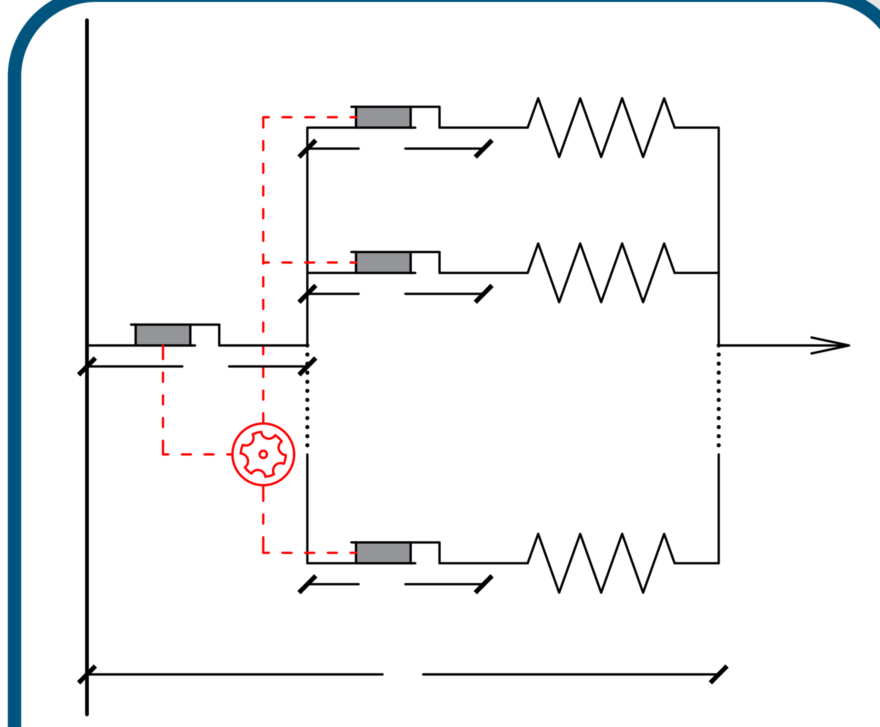
3 HARM

University of Oxford

The Hyperplastic Accelerated Ratcheting Model (HARM [2]) was developed at University of Oxford (Fig. 3).

The response to realistic storm loading is modelled directly with a ratchet attached to an Iwan model.

However, HARM is calibrated via higher cost model, laboratory and/or field tests on monopile foundations.



$$R = R_{ref}\left(\frac{\beta}{\beta_{ref}}\right)^{-m_r}\left(\frac{|\sigma|}{\sigma_{ref}}\right)^{m_s}$$

Fig. 3: HARM

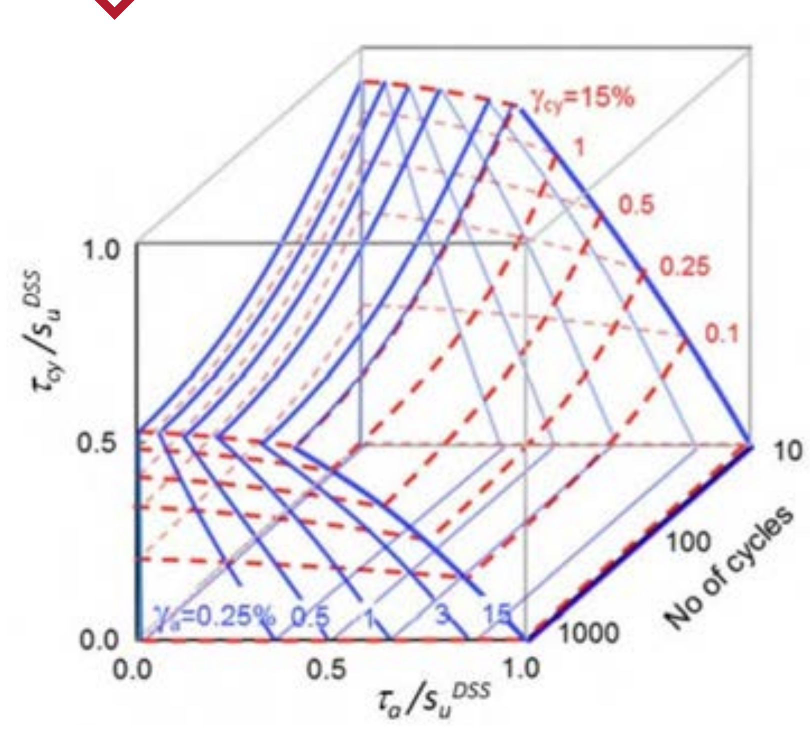
4 Proposed model

In this work, two existing models are combined:

1. Cyclic contour diagrams are calibrated against routine element tests.
2. Use UDCAM-S to predict monopile response during sinusoidal loading with different amplitude and asymmetry.
3. Calibrate HARM against the obtained UDCAM-S results.

The resulting model allows improved prediction of the monopile response during realistic storm loading from only laboratory test data.

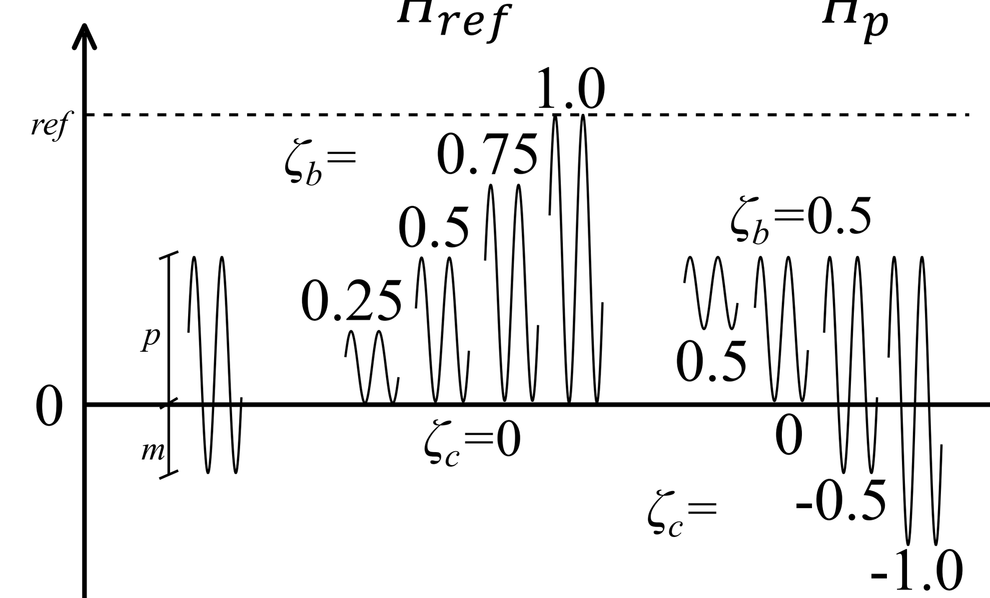
1



Example 3D cyclic contour diagram for OCR=1 Drammen Clay (reproduced from [1])

2

$$\zeta_b = \frac{H_p}{H_{ref}} \qquad \zeta_c = \frac{H_m}{H_p}$$



Different amplitude and asymmetry sinusoidal loading used as input to UDCAM-S model

3

HARM parameters calibrated to results of UDCAM-S analyses:

R_{ref} m_s m_r

Fig. 4: Proposed combined model

Acknowledgements
The author would like to acknowledge Prof. Byron Byrne from the University of Oxford for his support developing this project, as well as both Dr. Hans-Petter Jostad and Dr. Nallathamby Sivasithamparam from NGI for hosting a placement at NGI and sharing their knowledge of UDCAM-S.
The author was supported by a ECR fund made available by the Offshore Renewable Energy Supergen Hub project, Engineering and Physical Sciences Research Council grant no EP/Y016297/1.

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Fatigue in Offshore Wind Foundations

Comparison of S-N curves from various standards, new regression analyses, and parameters influencing the size effect in welds

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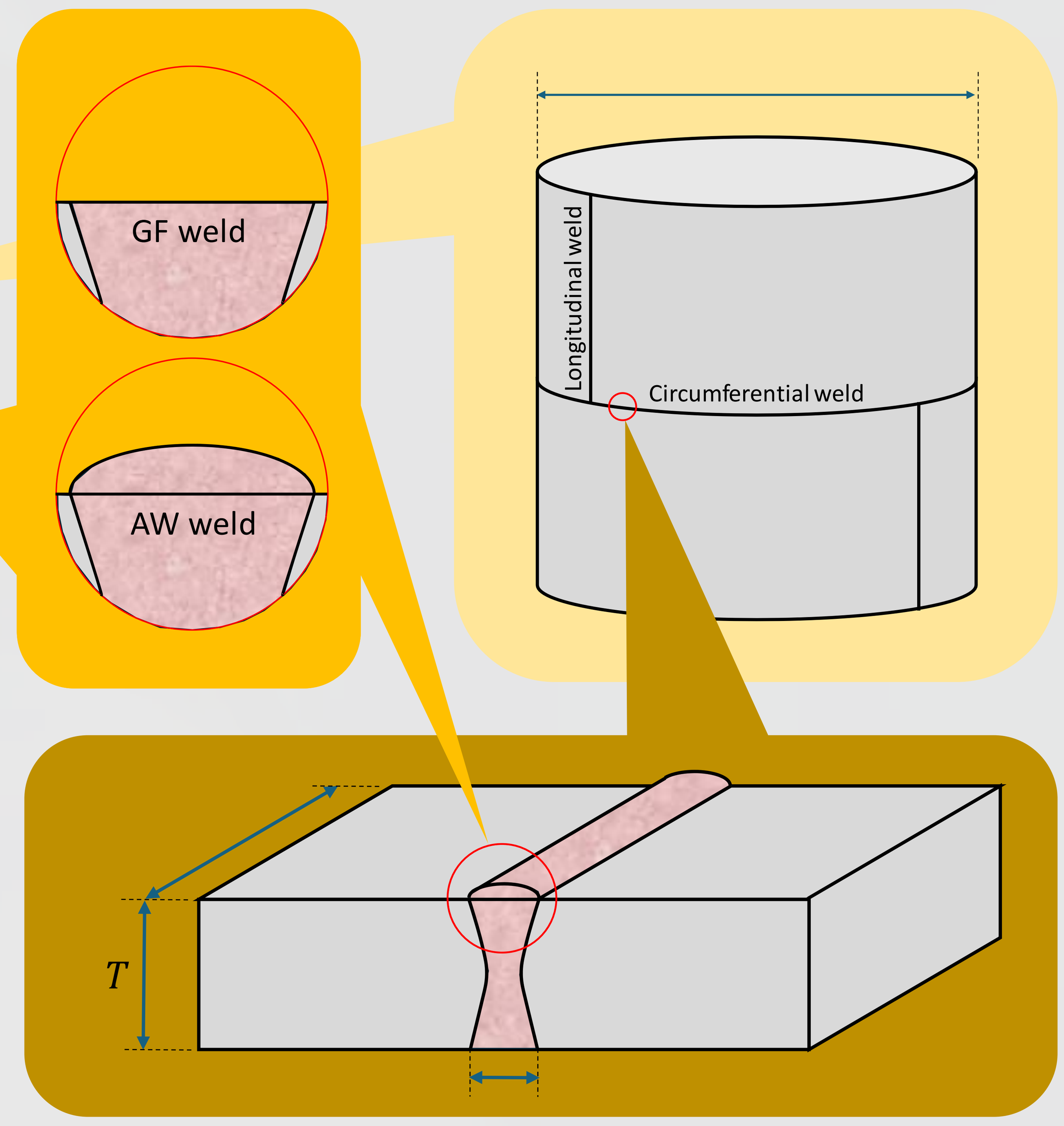
Background

The most common type of offshore wind turbine foundation is the monopile [1]:

- They are continuously subjected to cyclic loadings (i.e. fatigue) given as stress ranges ($\Delta\sigma$)
- They are increasing in size: up to 150 mm in wall thickness (T) and 10 m in diameter (D) [2]
- They are designed to operate for 20 to 30 years (i.e. they have to withstand more than 10^7 cycles)
- They contain double-V groove welds that can be ground flush (GF) or in as welded condition (AW)



S-N curve

A power law relates the number of cycles to failure (N_f) to the stress range ($\Delta\sigma$):

$$\log N_f = q - m \log \Delta\sigma$$

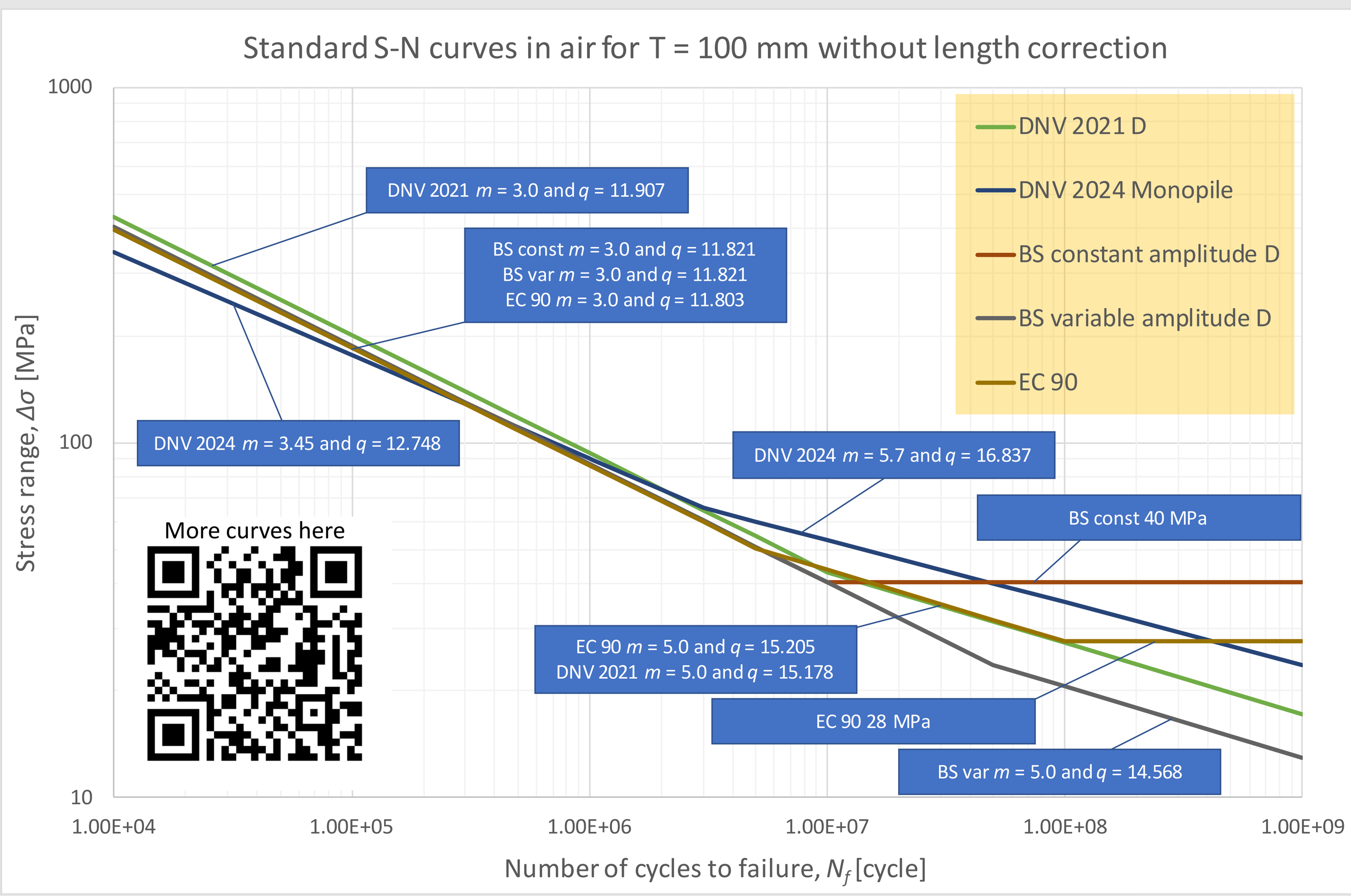
In log-log coordinates this is a straight line (with slope m and intercept q) called S-N curve.

Conditions of interest

Three standards were analysed in air, and seawater with (CP) and without (FC) cathodic protection:

- DNV-RP-C203-2021 (DNV 2021)
- DNV-RP-C203-2024 (DNV 2024)
- BS 7608:2014+A1:2015 (BS)
- EN 1993-1-9:2005:E (EC)

Class	DNV 2021	DNV 2024	BS	EC
GF	C1	C1	C	112
AW	D	Monopile	D	90



c	Air			Cathodic Protection			Free corrosion		
	DNV	BS	EC	DNV	BS	EC	DNV	BS	EC
GF	0.10	0	0.20	0.10	0	-	0.15	0	-
AW	0.20	0.20	0.20	0.20	0.20	-	0.20	0.20	-

Thickness reduction

All standards reduce fatigue life with the following formula when $T > 25\ mm$ ($t = T$ apart for DNV):

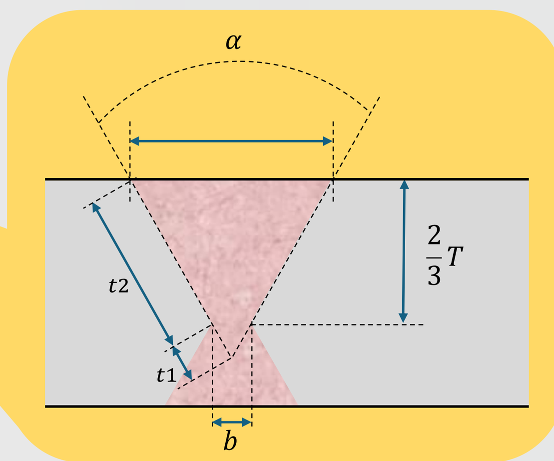
$$\log N_f = q - m \log \Delta\sigma - mc \log \frac{t}{25}$$

Weld width reduction

DNV suggests $t = \min(T, 14 + 0.66L_t)$ to weaken the thickness reduction at high T values.

For an asymmetric double V groove, the weld width L_t can be estimated as:

$$= 2(L_{t1} + L_{t2}) \sin\frac{\alpha}{2} = b + \frac{4}{3} T \tan\frac{\alpha}{2}$$



Using $\alpha = 60°$ and $b = 3\ mm$:

For $T < 32.5$, $\quad t = T$

For $T < 32.5$, $\quad t = 15.98 + 0.51T$

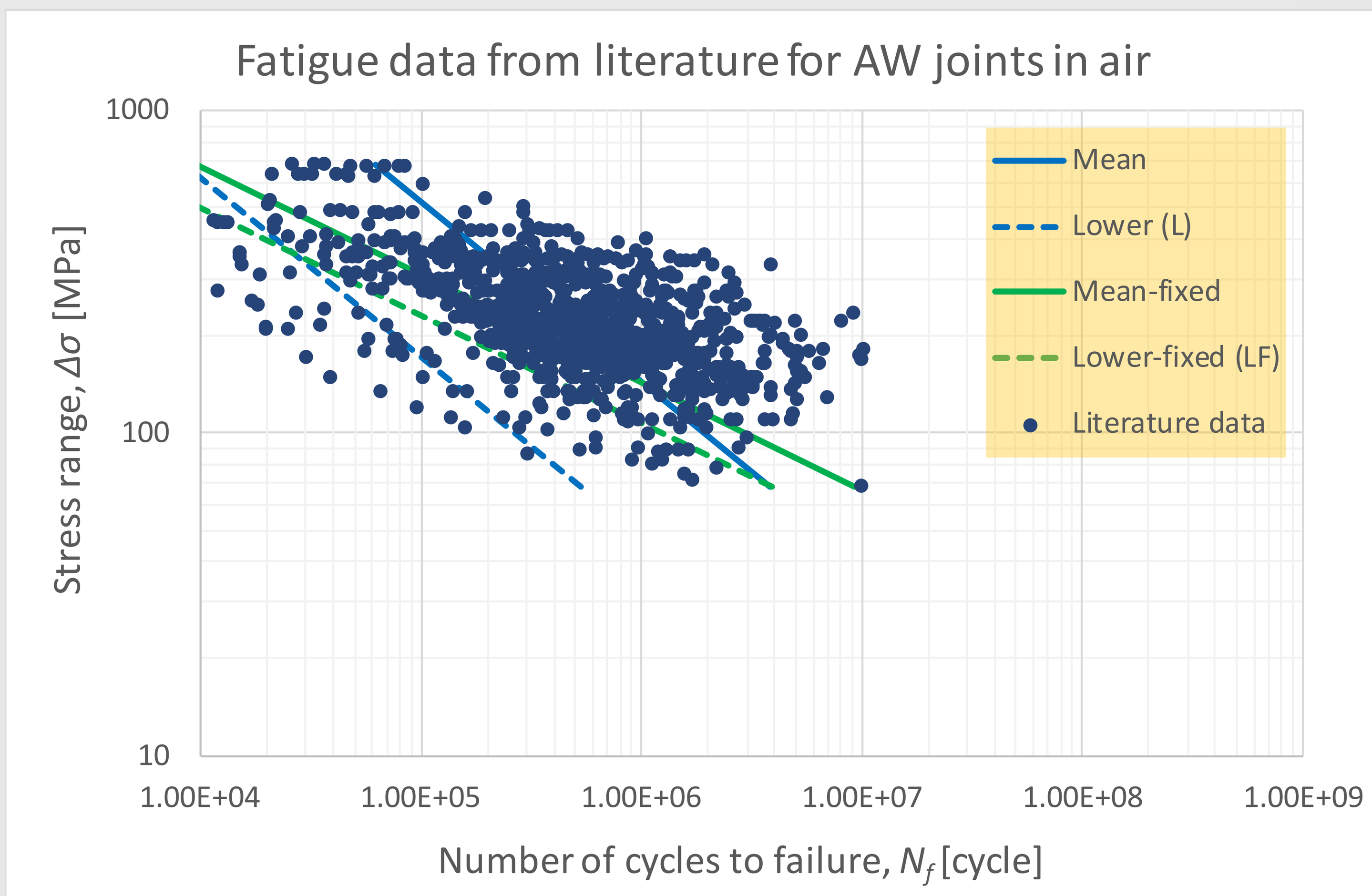
Weld length reduction

DNV standard suggests a further reduction for long welds (if $D = 8.0\ m$ the q is reduced by 0.24):

$$\log N_f = q - m \log \Delta\sigma - mc \log \frac{t}{25} - 0.1 \log\left(\frac{}{100}\right)$$

S-N curve comparison

- Standards suggest that in the ultrahigh-cycle fatigue (UHCF) regime (N_f after the change in slope), thick joints may encounter a further reduction in fatigue life due to the product between m and c.
- The most conservative standard in the UHCF is DNV 2021 for GF classes (regardless of thickness and environment) and thin AW joints in FC, and BS (with variable amplitude loads) for the others.
- For thin joints, disregarding the curves that display a horizontal asymptote in the UHCF regime, DNV 2024 is the least conservative in all environment apart from AW joints in free corrosion.
- For thick joints, disregarding the curves that display a horizontal asymptote in the UHCF regime, DNV 2024 is the least conservative for AW classes, while BS variable amplitude for the GF ones.
- The highest reduction in the allowable fatigue life is for AW joints in the UHCF: comparing plates 25 and 100 mm thick, a reduction up to 75% is obtained [3].



AW air 50mm	DNV 2021	DNV 2024	BS	EC	SLIC	L	LF
m	3.00	3.45	3.00	3.00	3.37	1.79	3.00
q	12.033	12.891	12.001	11.983	12.786	8.906	11.909
SD	0.20	0.20	0.21	-	0.21	0.43	0.19

New regression analyses

- The regression line is lowered by 2 standard deviation (SD) to get 2.3% probability of failure
- SLIC data brings to $m = 3.37$ for $T = 50\ mm$ AW joints (leading up to 30% increase in N_f) [4]
- Preliminary results using literature data: stresses were normalised to 25 mm, the slope was fixed (LF) or not (L) to 3, and the regression line (mean) was lowered by two SD and using $t = 50\ mm$.
- Due to experimental difficulties there is a lack of data at $N_f > 10^7$ especially for high T values.
- Future Bayesian regression will tell more about slopes and intercepts distributions, and allow the inclusion of runouts (suspended tests without failure) in the analyses.

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Engineering and Physical Sciences Research Council

Wind & Marine Energy Systems & Structures CDT

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Tidal Turbine Benchmarking Project:
Stage II – Experiments on Unsteady Loading in Waves

Yadong Han[1], Nijmeh Marouf[1], Ian Campbell[1], Ross Calvert[2], Christopher Vogel[1], Richard Willden[1]

[1] Department of Engineering Science, University of Oxford, [2] University of Edinburgh

Introduction

- **Motivation**

  Unsteady loading and the instability to confidently predict unsteady loading and / or quantify errors drives unnecessary redundancy and design conservatism.

  Open access benchmarking datasets are available for the wind energy sector, but little is available for the tidal energy sector.
- **Objectives**

  Improve accuracy of modelling techniques.

  Improve confidence in the use of modelling techniques.

  Quantify modelling errors for different techniques under different loading scenarios.

  Development of novel measurement techniques.
- **Approaches**

  Conduct large laboratory tests of a highly instrumented tidal turbine in turbulent flow and waves to provide underlying data.

  Conduct a series of community wide (academia and industry) blind prediction exercises with staged data release, leading to an open access dataset.

Experimental Campaigns

- **Stage I: Steady Flow Experiments, July 2021 – January 2023**

  Turbulence Grid and wave characterization experiments

  Steady and turbulent flow experiments

  Preliminary wave experiments

  Blind prediction campaigns
- **Stage II: Experiments on Unsteady Loading in Waves, March 2025 – 2026**

  Wave characterization

  Wave experiments covering **20 wave conditions**

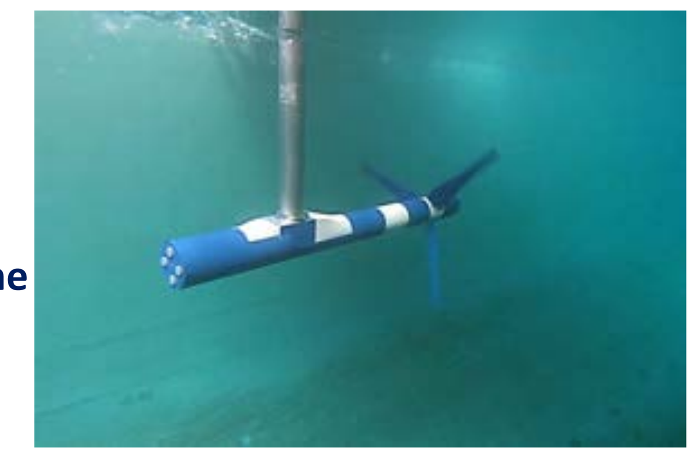
  Frequency (Hz): 0.225, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5

  Amplitude (m): 0.025, 0.035, 0.05, 0.075, 0.1

  Additional steady flow **experiments with yawed turbine**

  Total of **175 tests** performed

  Blind prediction campaigns and data dissemination



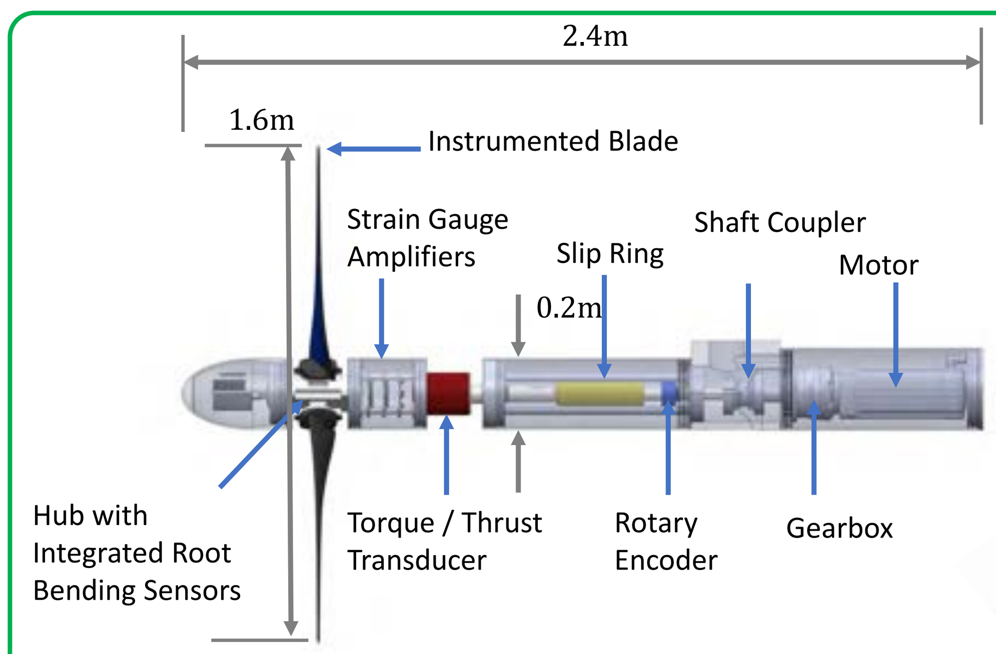
Turbine Instrumentation and Experimental Facilities

- **Turbine Instrumentation**

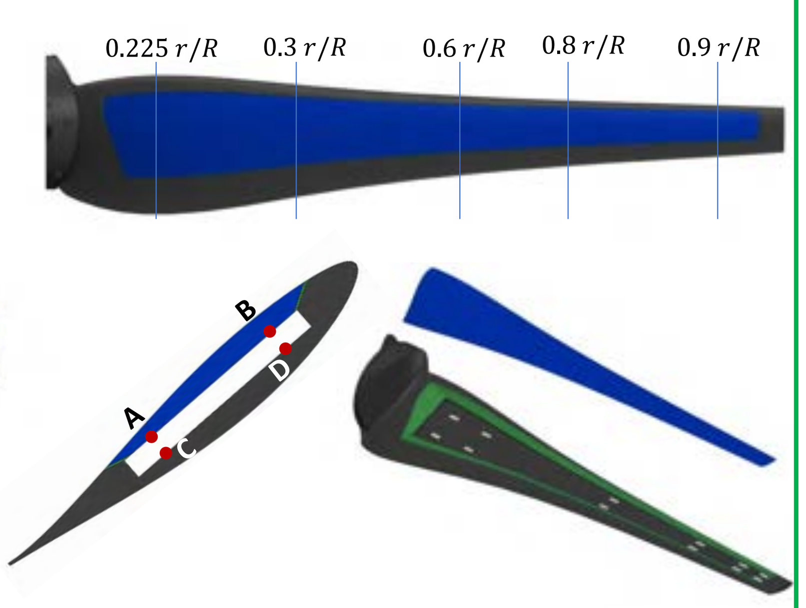
  1.6m diameter rotor / 0.2m diameter nacelle

  Instrumented blades with strain gauges, integrated **root bending sensors** (100 strain gauges)

  Torque and Thrust transducers, **Shaft rotary encoder** for speed and position



Highly Instrumented Turbine



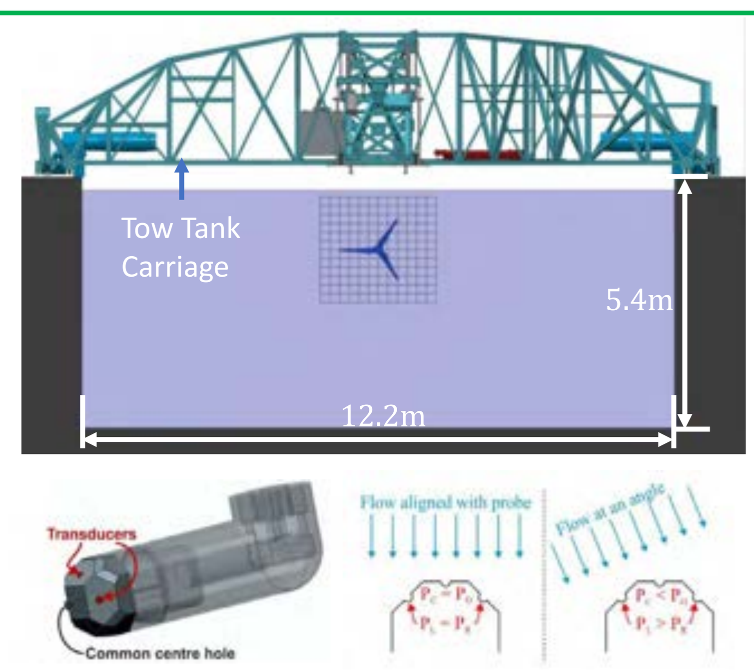
Baldes Instrumented with Strain Gauges

- **QinetiQ Towing Tank Facility (270m (L) x 12.2m (W) x 5.4m (D))**

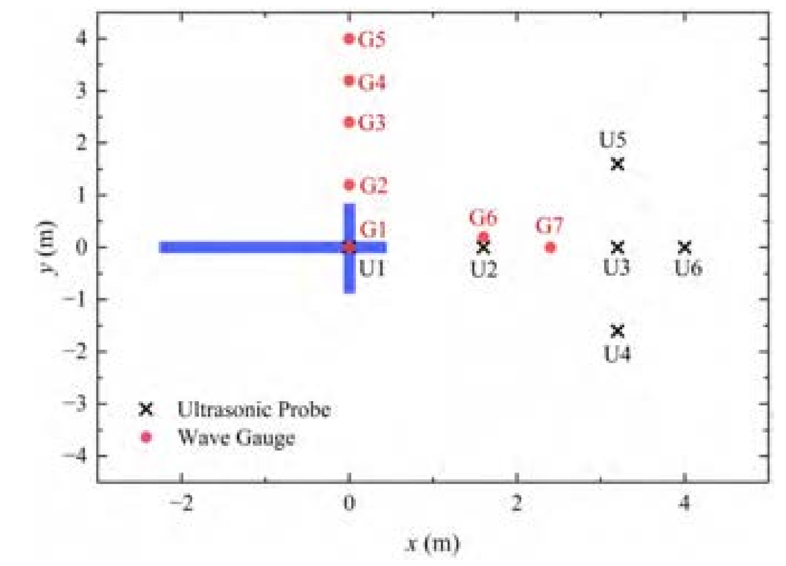
  Rake of 5-hole **Barnacle Probes** developed by Bath.

  Solid Wave Gauges and **Ultrasonic Probes** are mounted on the carriage.

  Tow speed 1m/s, Tow length approx. 150m, Settling time ~15mins



5-Hole Unsteady Barnacle Probe



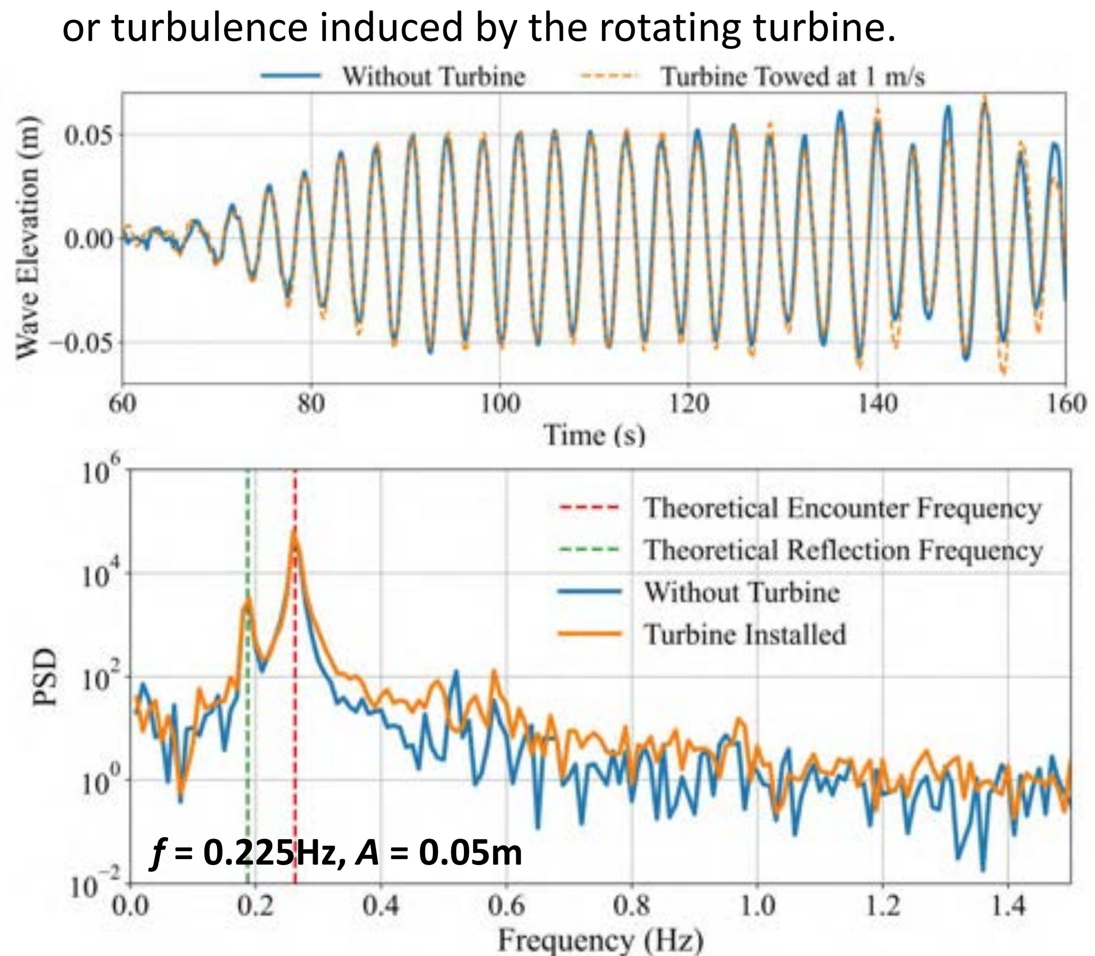
Wave Gauge and Ultrasonic Probe Locations

Wave Data Analysis

- **Wave Elevation Comparison: With and Without Turbine**

  Wave amplitudes remain consistent in clean wave cycles. The dominant wave frequencies are highly stable, with minimal variation observed between tests.

  The installed turbine has negligible influence on the energy content of both the incident and reflected wave components, but it introduces a slight increase in energy at higher frequencies, due to flow disturbances or turbulence induced by the rotating turbine.



Impact of the Turbine on Wave Field

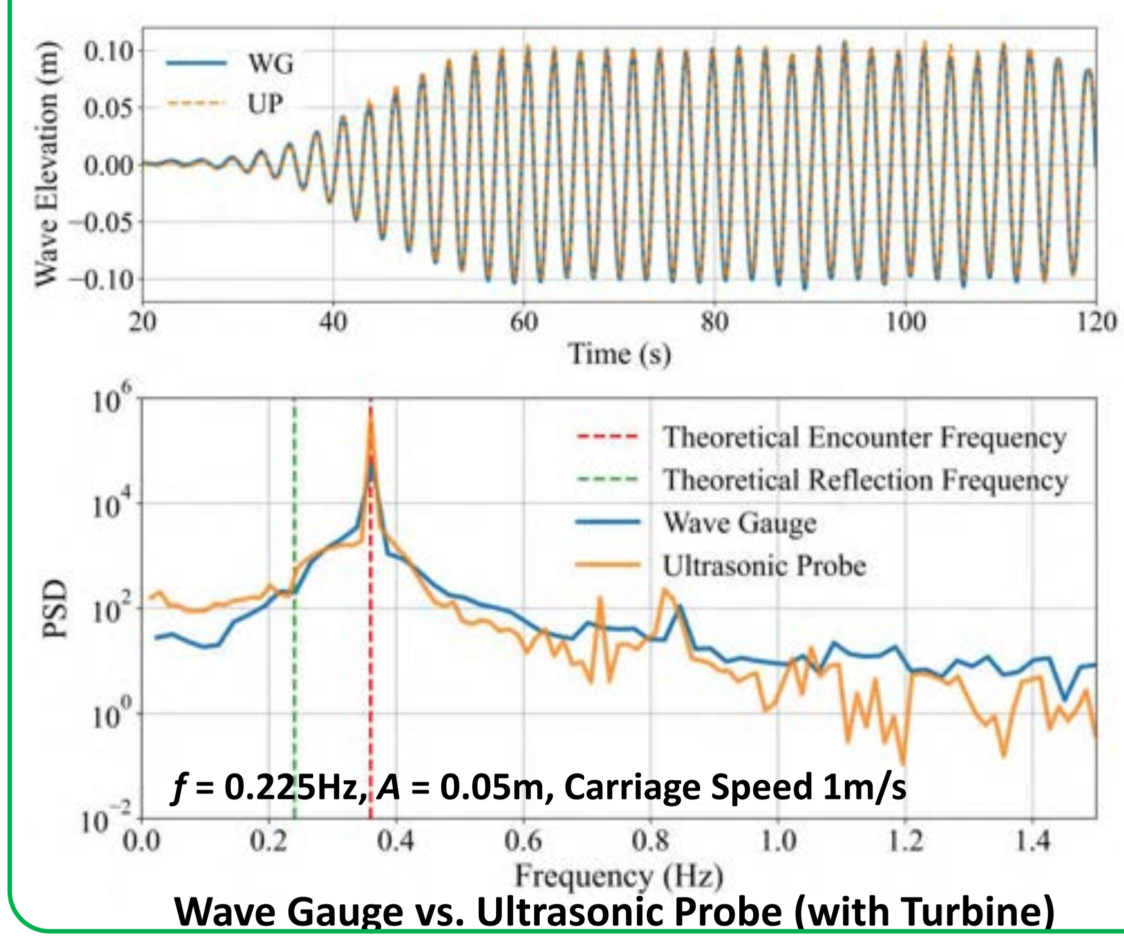
- **Reliability of Wave Elevation Measurements**

  Wave Gauge (WG) and the Ultrasonic Probe (UP) show excellent agreement in both amplitude and phase.

  The overall spectral shape is consistent, and UP signal shows slightly more noise at higher frequencies.

  These results confirm the reliability and consistency of wave elevation measurements.

  The energy of the reflected waves is significantly lower than that of the incident waves in this case.

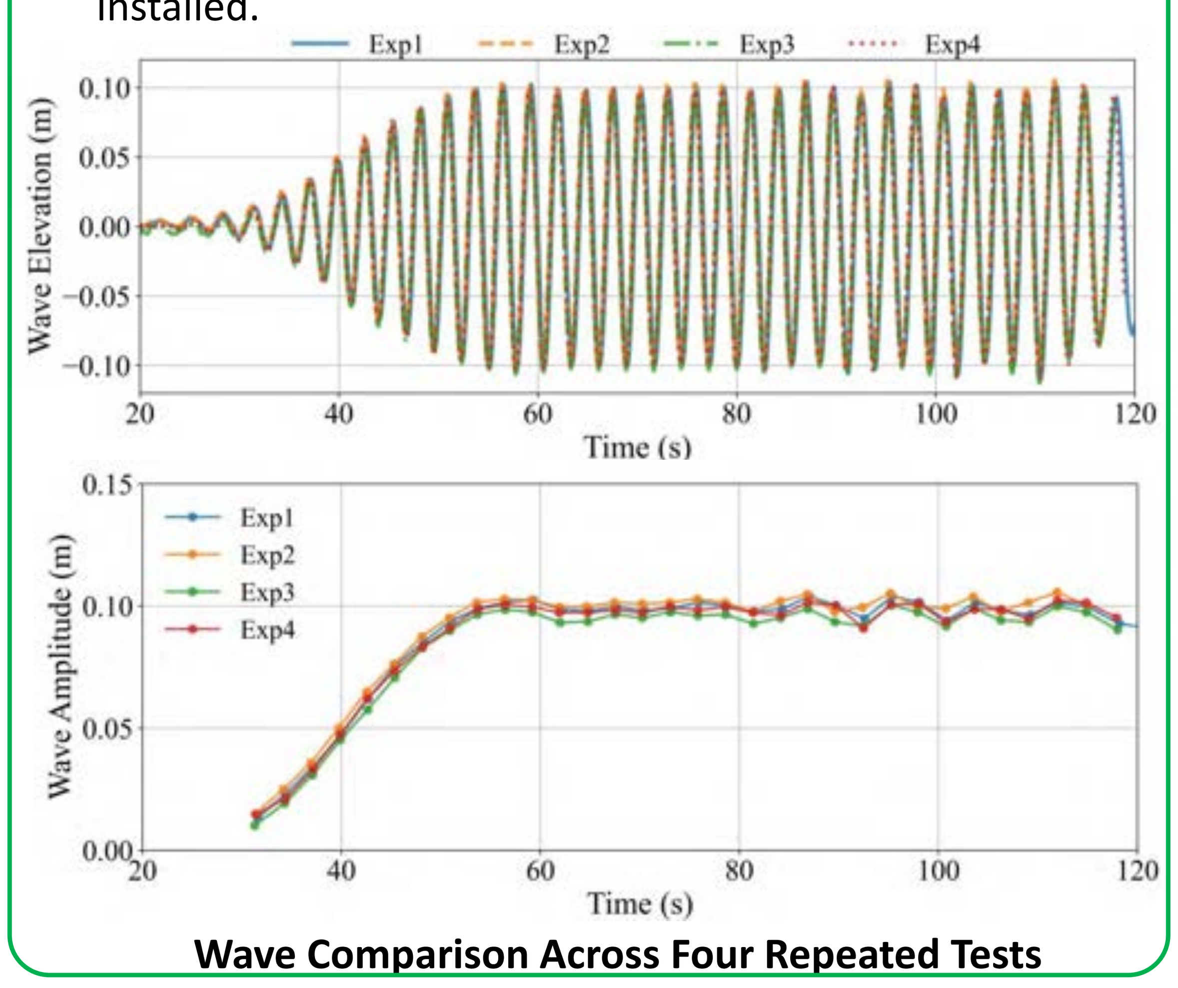


Wave Gauge vs. Ultrasonic Probe (with Turbine)

- **Wave Repeatability in Turbine Experiments**

  Multiple test repeats show nearly identical waveforms. The amplitude envelopes of all four tests are very closely aligned over the entire test duration. Slight variations may be observed, but they remain within a small range (~mm scale).

  These results confirm excellent repeatability in wave generation and measurement, even with the turbine installed.



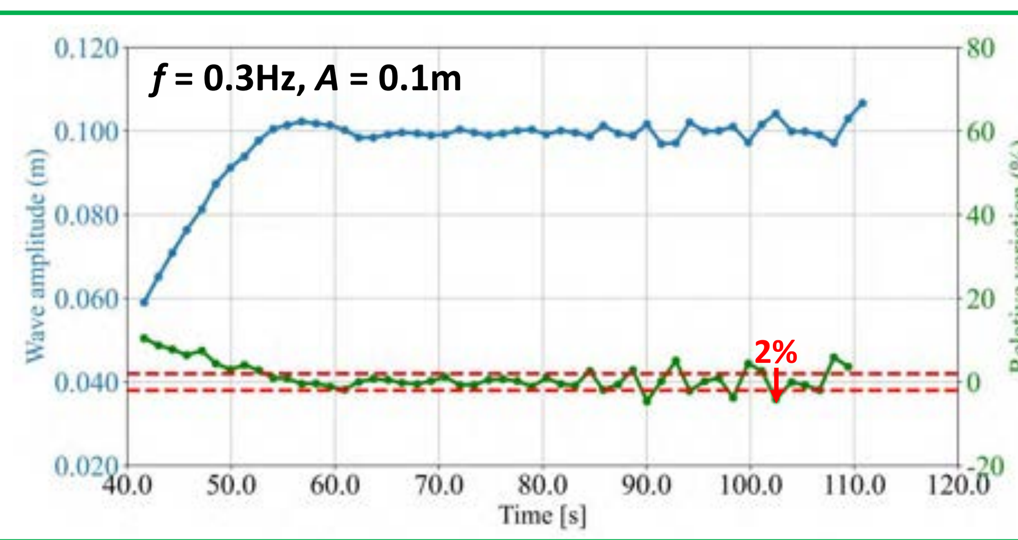
Wave Comparison Across Four Repeated Tests

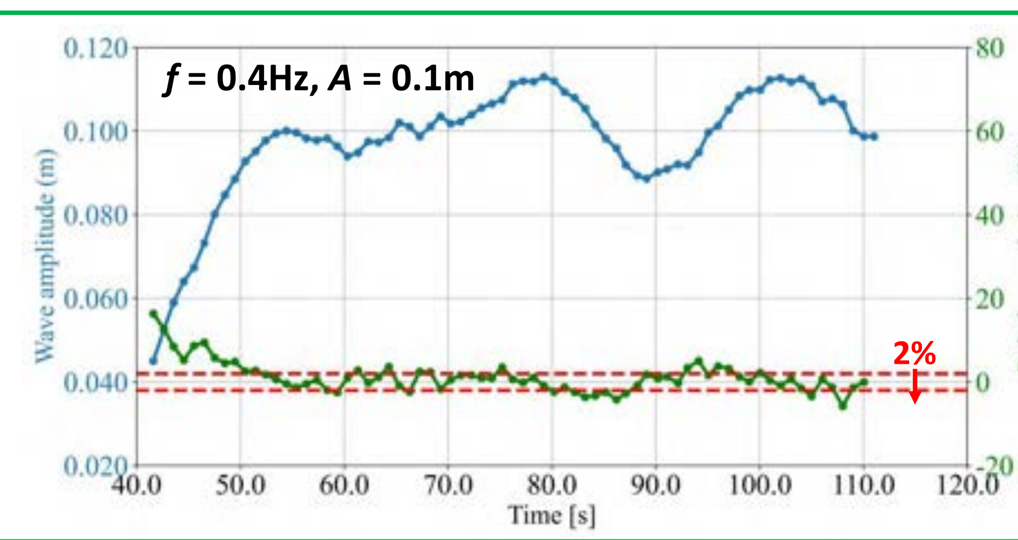
- **Selection of stable wave cycles**

  Incident wave data analyzed for each case.

  Cycle-to-cycle variations in wave elevation and turbine torque of **less than 2%** result in **5-12 wave cycles** being identified for further analysis.

  The useful wave cycles identified from each test are combined with those obtained from repeated tests under the same conditions.





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Fei He, University of Oxford

Job Title: PDRA

Academic Discipline: Fluid mechanics

Flows through porous obstructions are ubiquitous in natural and engineered systems, such as patches of aquatic vegetation, groups of bridge piers, foundation piles, space-frame offshore structures and arrays of tidal/wind turbines. To first approximation, these porous obstructions can be modelled as a circular array of cylinders.

When flow encounters a porous array, a portion flows through it (bleeding flow), resulting in wake formation behind individual elements interacting with each other (element-scale wake interaction) and a region of reduced flow developing behind the entire array (array-scale wake). These three key elements of the flow play a critical role in many practical applications. For instance, whilst the bleeding flow velocity and the interaction between element-scale wakes of individual turbines affect the efficiency of power generation with a turbine farm, the array-scale wake structure determines morphology downstream of the farm. Similarly, the bleeding velocity influences rates of sediment transport and nutrient uptake for vegetation patches and governs hydrodynamic forces on offshore structures.

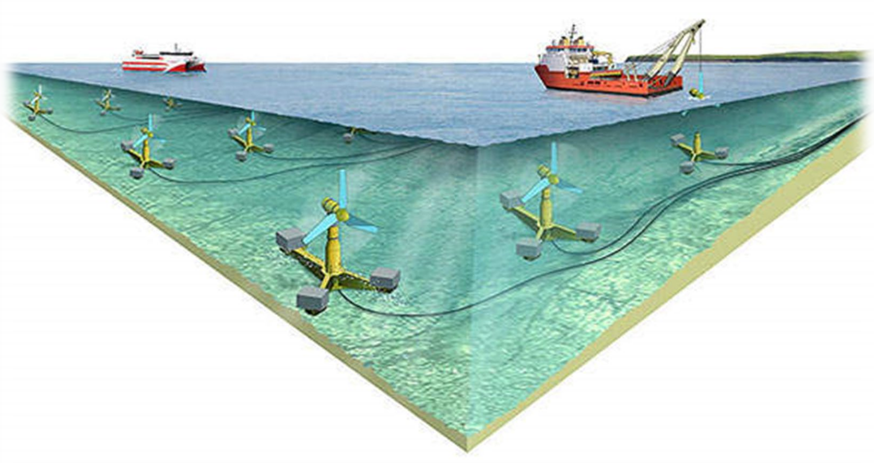
This presentation provides a systematic investigation on flow through a porous obstruction, modelled by an array of emergent cylinders, across wide and relevant ranges of flow and array geometries. Through integrating outcomes from laboratory experiments, direct numerical simulations, and theoretic modelling, mechanistic frameworks for describing and predicting flow through a porous array are proposed based only on the array geometrya and incident flow characteristics.

Tidal Resource Assessment for the Co-Tide Project

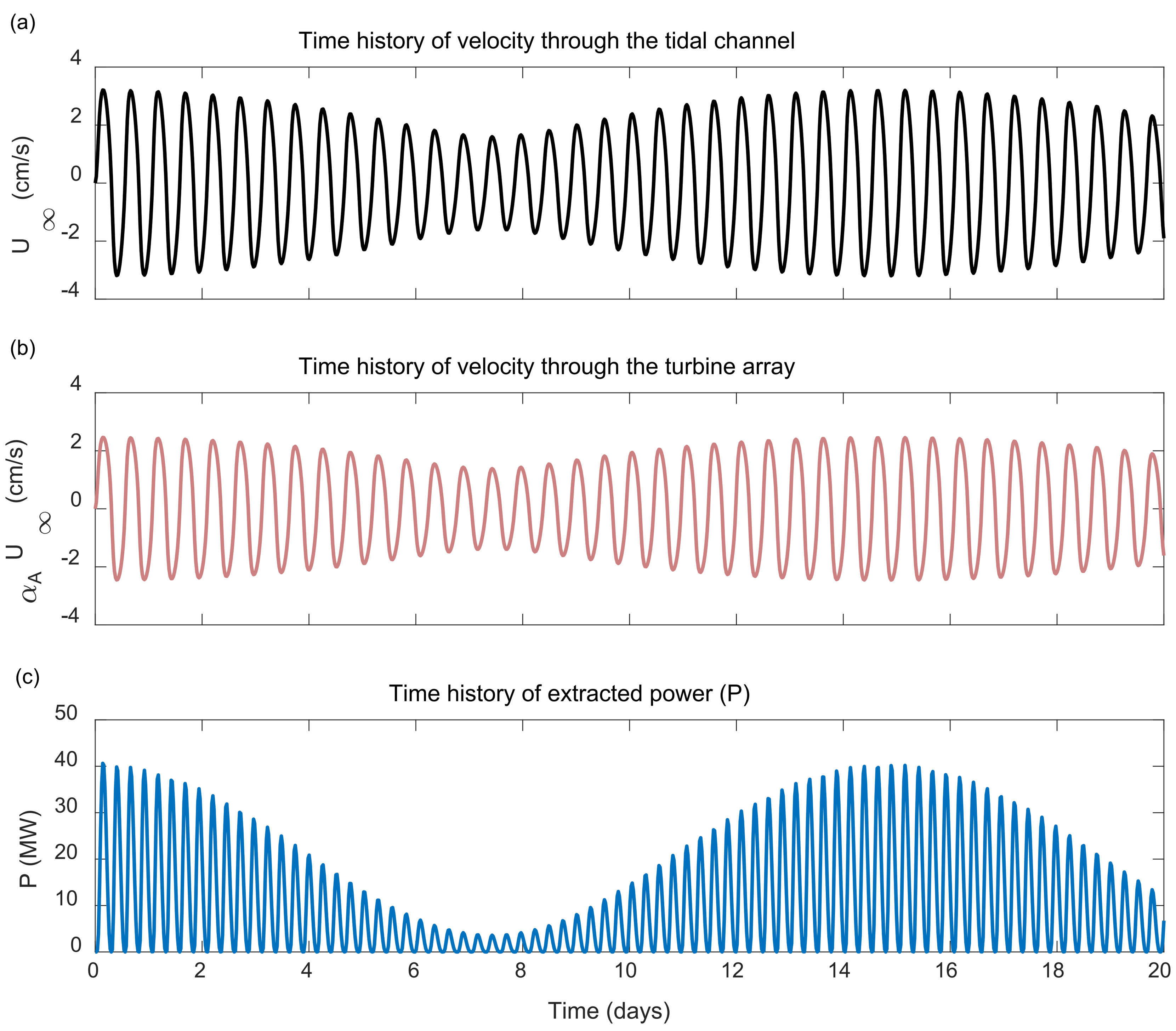
Fei He, Christopher Vogel, Thomas Adcock
Department of Engineering Science, University of Oxford

INTRODUCTION

- Much of the global tidal current energy resource lies in the accelerated flows along narrow tidal channels that have the potential to produce 10–1000s of MW of electricity.
- However, realising 100MW of a channel's potential is much more complex than just installing 100 1-MW turbines and, more importantly, not all the tidal energy can be extracted due to different real constraints!
- Tidal Resource Assessment evaluates the potential of a tidal site for energy extraction using turbines arrays, providing insights into the feasibility and value of planning and deploying tidal energy projects.
- **The aim is to develop an analytical framework for quick tidal resource assessment.**

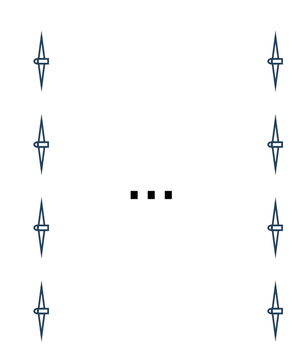



RESULT

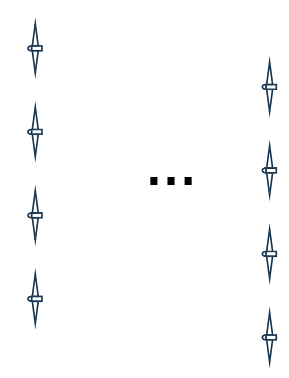


FUTURE WORK

- How does the 1-D analytical framework compare with 2-D numerical simulations?
- Can this framework be extended to an array of multiple rows of turbines and different channel geometries?
- Does arrangement of tidal turbines matter for power generation?



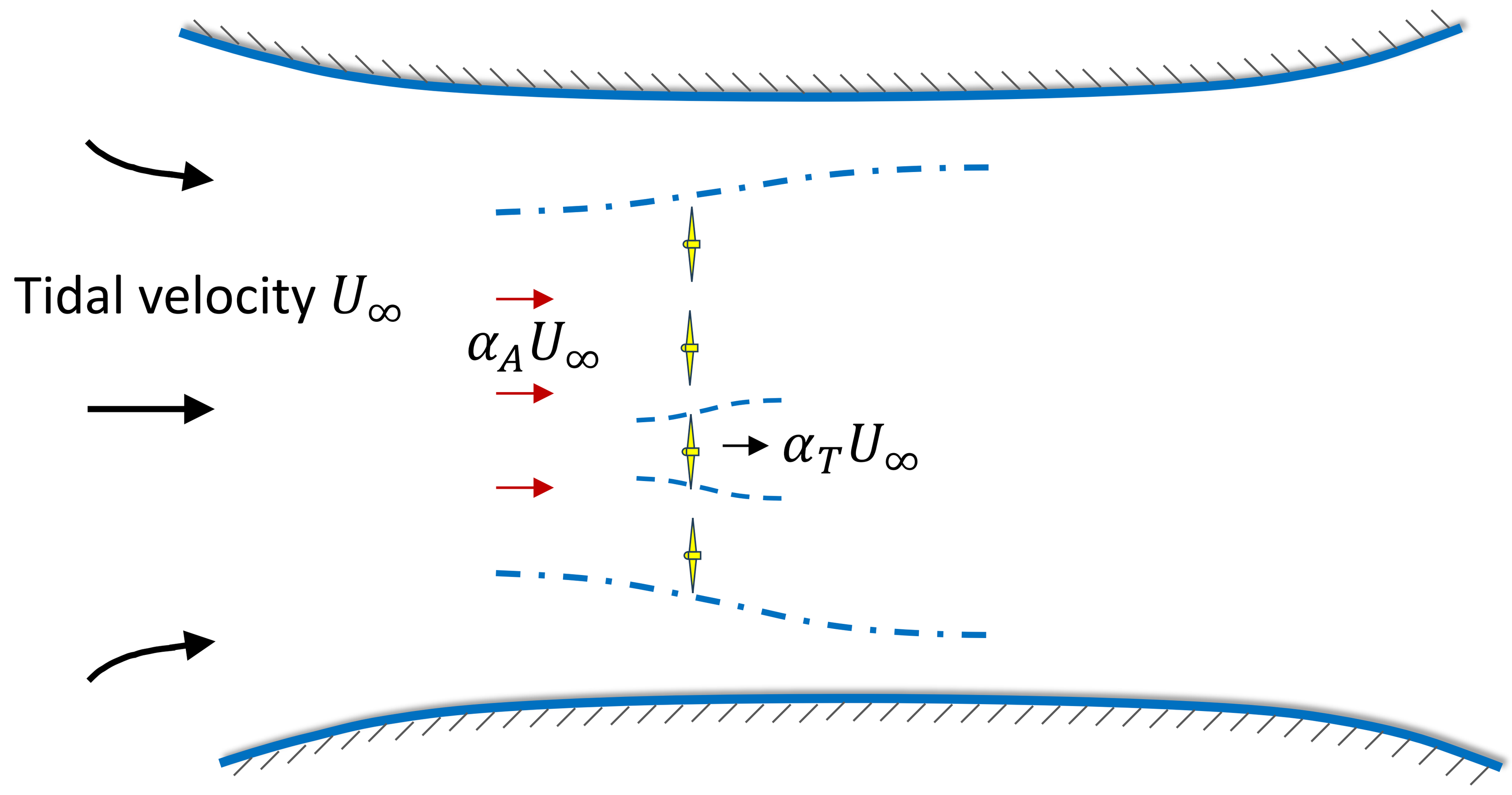
(a) Inline array



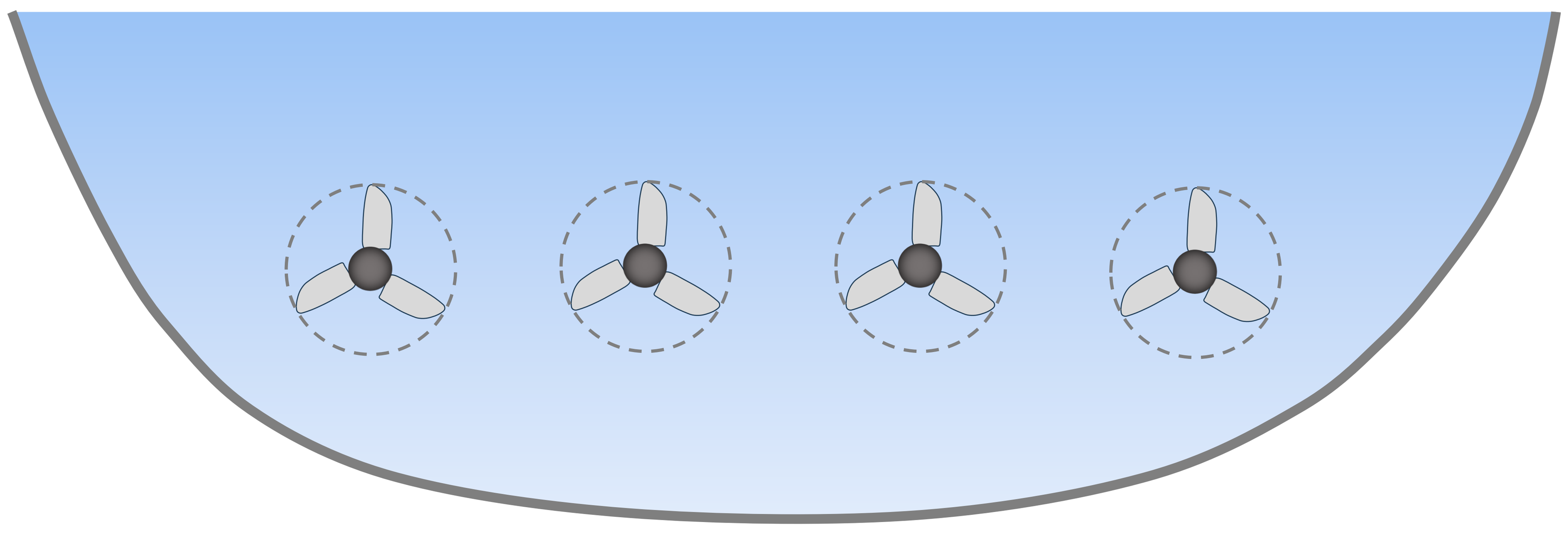
(b) Staggered array

Google Scholar

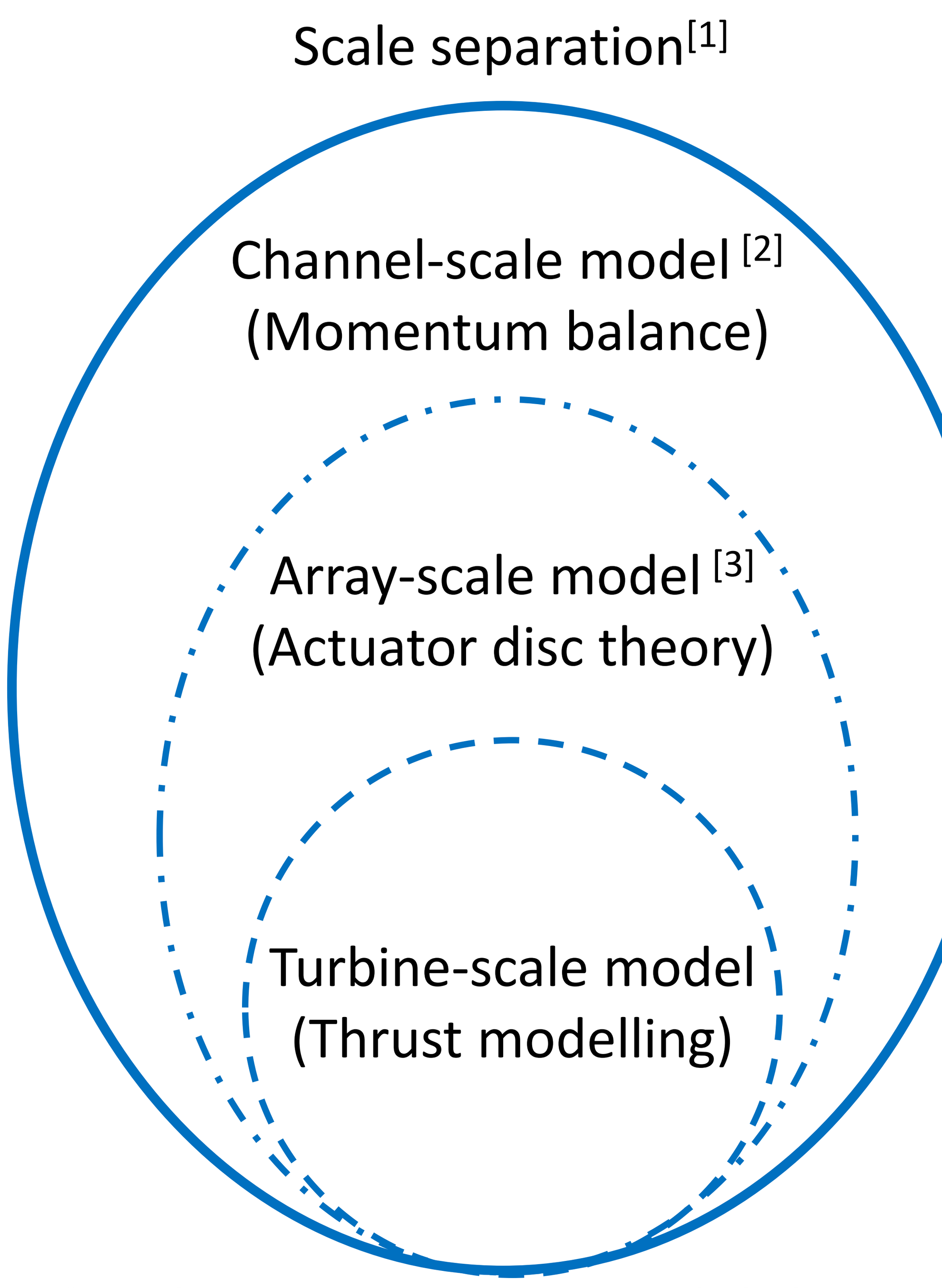
METHODOLOGY



(a) Top-down view of a row of turbines in a tidal channel



(b) Cross-sectional view of tidal turbines



(c) Using idea of scale separation to model the system separately at different scales and then couple together through net thrust

REFERENCE

[1] Nishino, T., & Willden, R. H. (2012). The efficiency of an array of tidal turbines partially blocking a wide channel.
[2] Garrett, C., & Cummins, P. (2005). The power potential of tidal currents in channels.
[3] Garrett, C., & Cummins, P. (2007). The efficiency of a turbine in a tidal channel.
[4] Image Credit: Andrey Armyagov/Shutterstock.com
[5] Image Credit: https://www.power-technology.com/projects/pentland-firth-tidal-power-plant-scotland

ACKNOWLEDGEMENT

EPSRC Engineering and Physical Sciences Research Council
Department of Engineering Science
Co-Tide Project

Madhubhashitha Herath, University of Hull

Job Title: Post Doctoral Researcher

Academic Discipline: Mechanical and Manufacturing Engineering

Subsea power cables are critical assets for offshore renewable energy systems. Failures of subsea power cable leads to significant costs due to long outage times and high repair expenses. The cable failures dues to external mechanical loads during transportation, installation and operation are critical and the condition monitoring of the cables has the potential to prevent unexpected damages. This research will analyse the bending of power cables using embedded optical fibre sensors. In the initial stage of the research, a 6 m long and 40 mm diameter Polybutylene conduit was used to experimentally analyse long cylindrical members subjected to large bending deformations. 125 μm diameter single mode optical fibres were attached to the outer surface of the Polybutylene conduit in two configurations, in parallel to the axis of the conduit and in helical windings around the conduit. A custom-made test rig was used to bend the conduit under 3-point bending and circular bending arrangements. The strain changes were measured using a Brillouin Optical Time Domain Reflectometer (BOTDR) which allows strain measurement over long distances in standard optical fibres, without special gratings. The strain patterns along the fibre distinguish between the shapes of a 3-point bend and a circular bend. The measured strain values were proportional to the magnitude of the large deformation. It was revealed that employing three or more optical fibres around a cylindrical member enables the monitoring of the bending direction of the cylindrical member. An inverse analysis based on the strain data is being conducting to predict the bending radius and the shape. Optical fibre embedded cylindrical sensing cables are proposed to be integrated within three-core power cables to monitor and predict their bending throughout the different stages of their lifecycle.

Distributed Optical Fibre Sensing for Monitoring of Large Bending Deformations of Subsea Power Cables

Dr. Madhubhashitha Herath[1] and Prof. James Gilbert[2]
[1] School of Engineering, Faculty of Science and Engineering, University of Hull, Hull, United Kingdom
[2] Energy and Environment Institute, University of Hull, Hull, United Kingdom

Introduction

Subsea power cables are critical assets for offshore renewable energy systems. Failures of subsea power cables lead to significant costs due to long outage times and high repair expenses [1]. The cable failures due to external mechanical loads during transportation, installation and operation are critical and condition monitoring of the cables can benefit to prevent unexpected damages [2]. This research intends to monitor the large bending deformations of the power cables using embedded optical fibre sensors.

Methods

In the initial stage of the research, a 6 m long and 40 mm diameter Polybutylene conduit (hollow) was used for experimental analysis of the bending behaviours of long cylindrical members subjected to large bending deformations. 125 μm diameter single mode optical fibres were attached to the outer surface of the Polybutylene conduit in two configurations, in parallel to the axis of the conduit and in helical windings around the conduit.

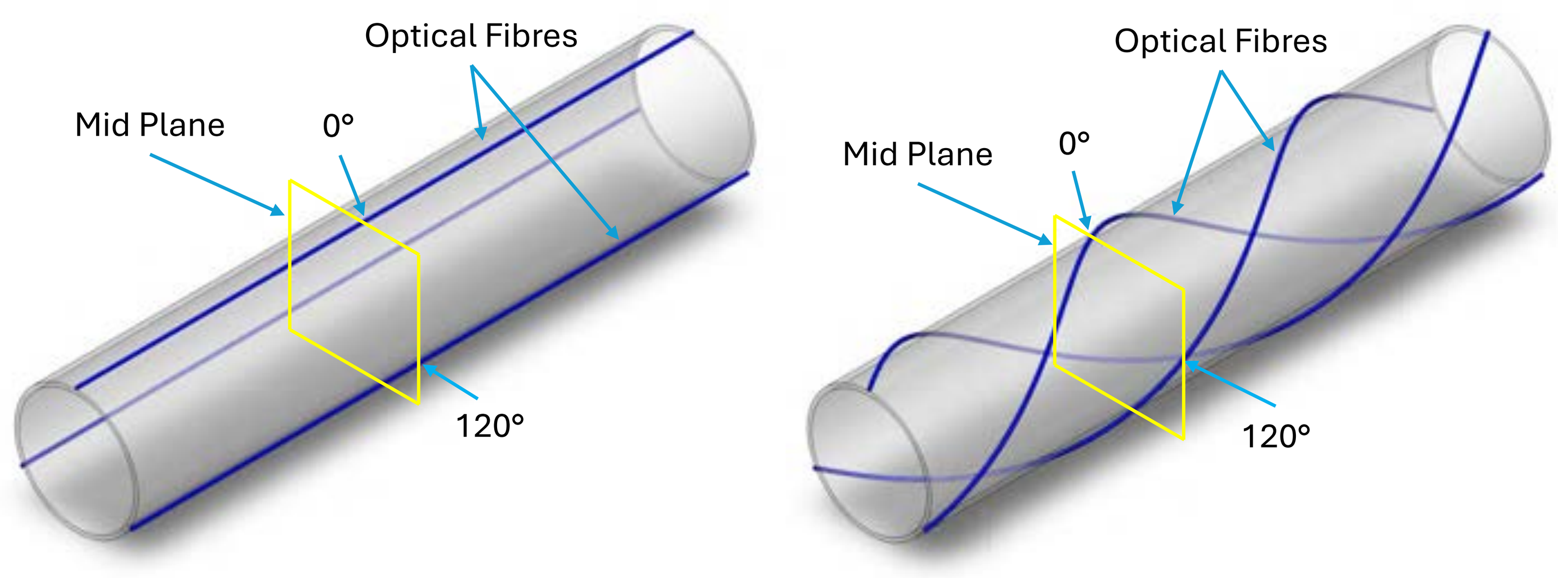
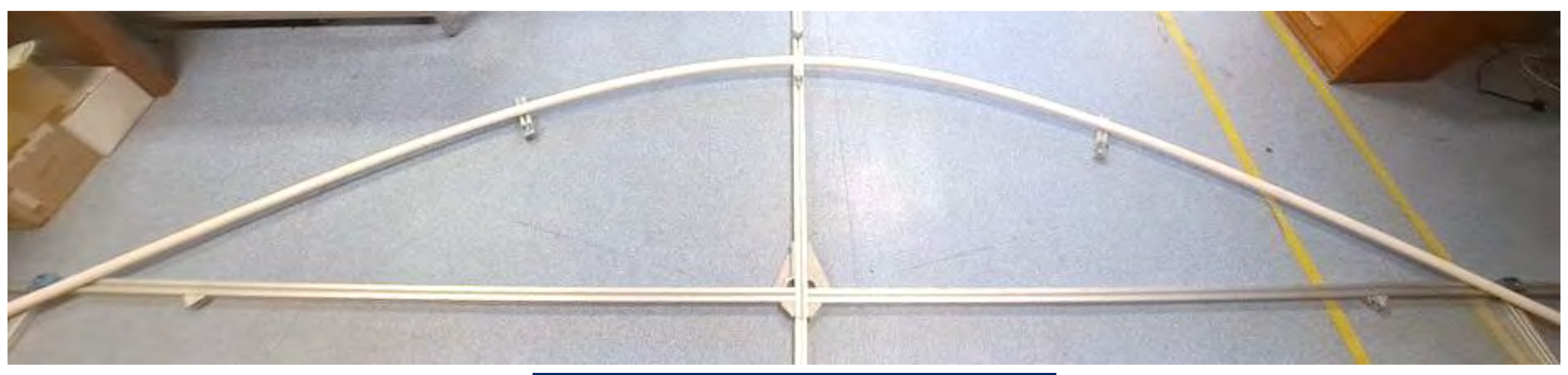


Figure 1: Configurations of the optical fibre attached to the outer surface of the Polybutylene conduit

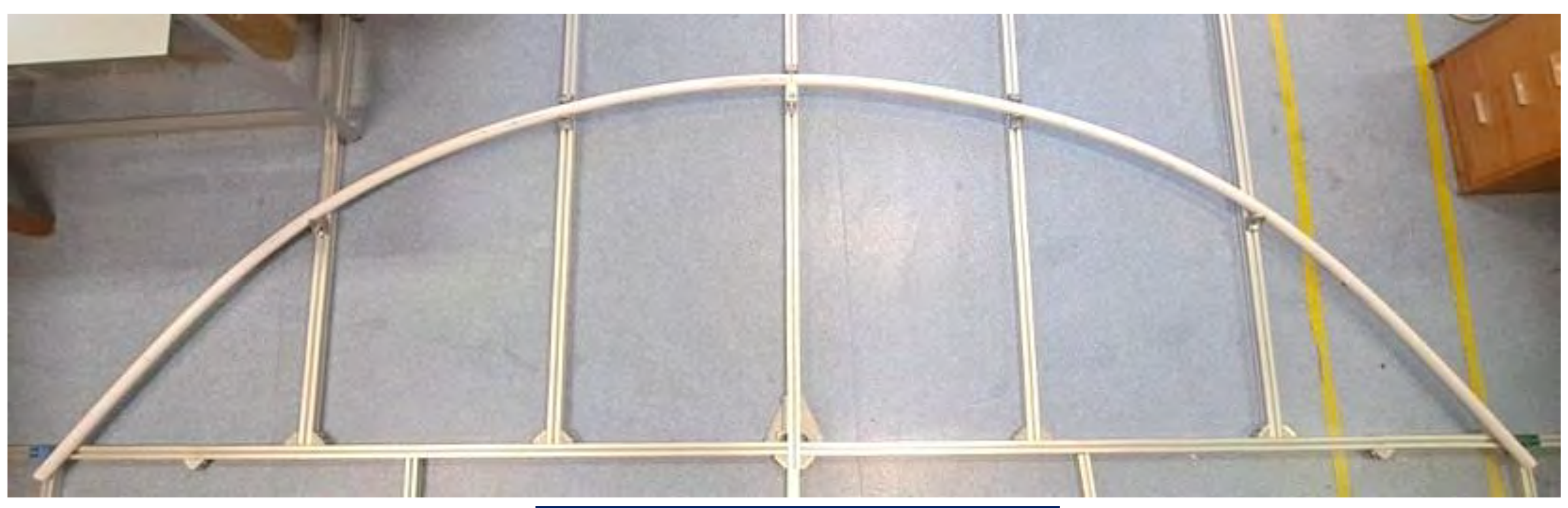
A custom-made test rig was used to bend the conduit under 3-point bending and circular bending arrangements. The span for all the tests was 5 m. Both tests were conducted for five levels of deformations. The strain changes were measured using a VIAVI FTH-9000 Brillouin optical time domain reflectometer (BOTDR).

Table 1: Deformation magnitude levels of the bending tests

Midspan Displacements (MSD) of the 3 Point Bending Test	**1.34 m**	**0.76 m**	**0.55 m**	**0.43 m**	**0.35 m**
Bending Radiuses (BR) of the Circular Bending Test	**3 m**	**4.5 m**	**6 m**	**7.5 m**	**9 m**



3 Point Bending



Circular Bending

Figure 2: Bending configurations on the test rig

A series of 3 point bending tests were conducted to study the bending direction by changing the mid plane crossing location of the optical fibre sensor. The top dead centre of the mid plane was considered as 0° and CW rotational angles of 30°, 60°, 90°, 120°, 150° and 180° were considered for the experiment.

Results

The strain values along the fibre were proportional to the magnitude of the deformation. The strain patterns distinguish between the shapes of a 3-point bend and a circular bend. The strain measured by the optical fibre sensors at different mid plane crossing locations showed proportional magnitudes of tension and compression relative to the direction of the measured bending.

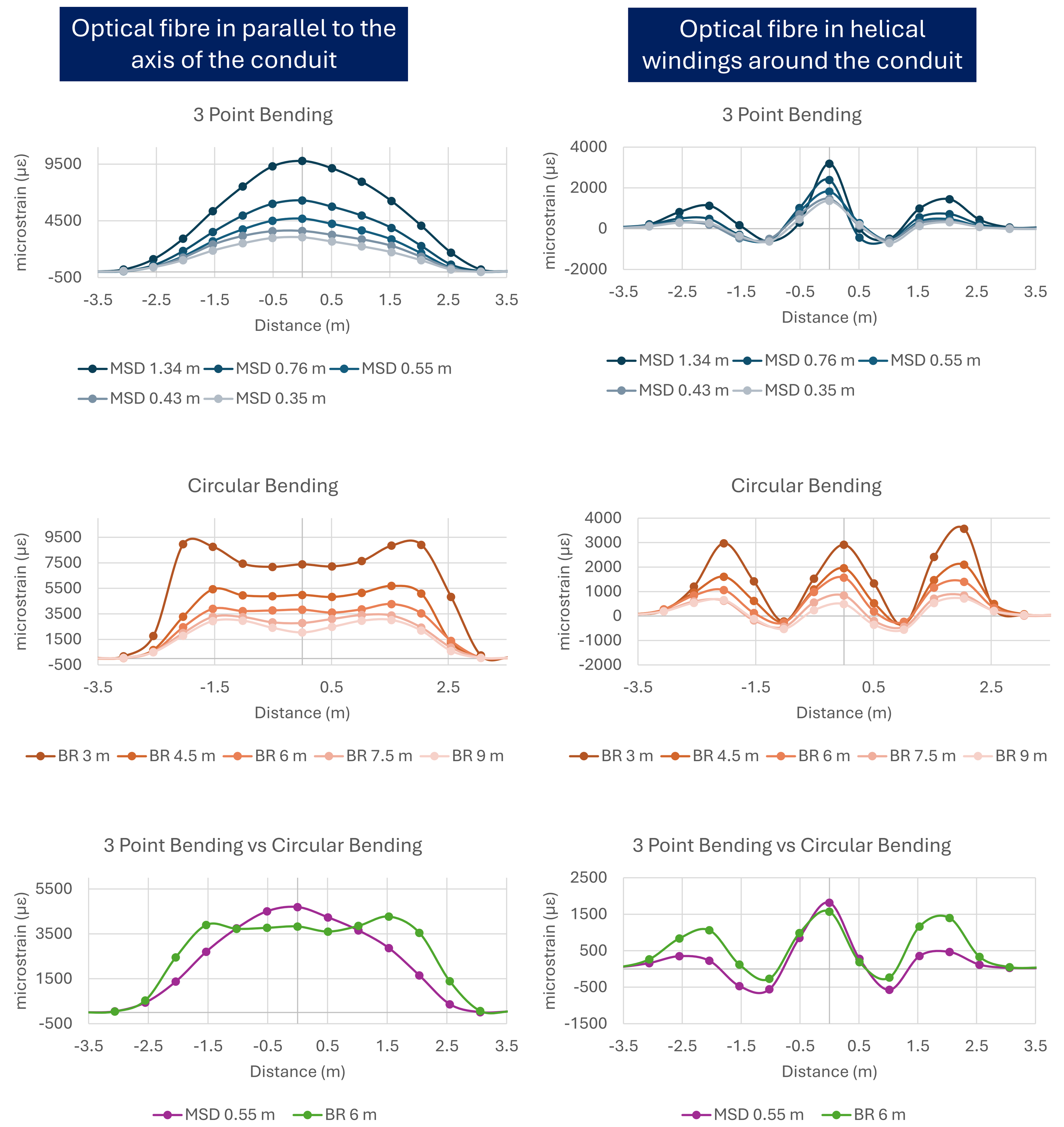


Figure 3: Strain data along the Polybutylene conduit under different magnitudes of the deformation.

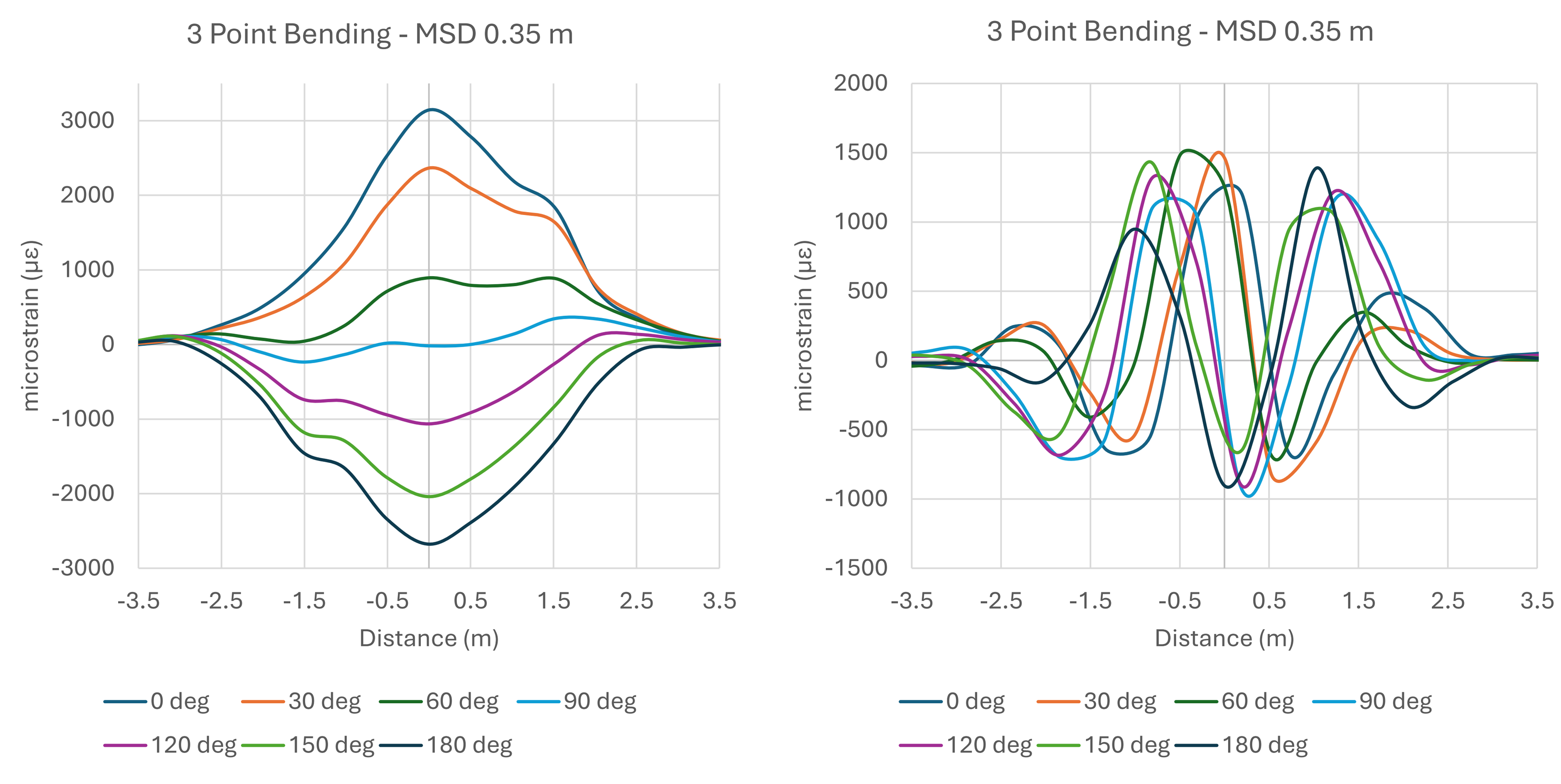


Figure 4: Strain data along the Polybutylene conduit measured by the optical fibre sensors with different mid plane crossing locations denoted by the rotational angle.

Conclusion and Future Directions

Employing three or more optical fibre sensors around a cylindrical member in parallel or helical configurations can analysis the magnitude and direction of the member subjected to a large bending deformation. Optical fibre embedded cylindrical sensing cables are propose to be integrated within three-core power cables to monitor and predict the bending throughout the different stages of their lifecycle.

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UNIVERSITY of HULL
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Supergen Offshore Renewable Energy

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Job Title: Postdoctoral Research Assistant

Academic Discipline: Civil and Geotechnical Engineering

Ioannis Kamas [*a], Harvey J. Burd [a], Byron W. Byrne [a]

[a] *Department of Engineering Science*

Monopiles are the most widely used foundation type for supporting offshore wind turbines. In current design practice, the monotonic response of laterally loaded monopiles is typically analysed using one-dimensional (1D) models, where the monopile is represented as an embedded beam. In previous work, a 1D design model – known as the 'PISA design model' [2] – was developed in which the soil/pile interaction is represented by functions known as 'soil reaction curves'. The parameters for these curves are directly calibrated through detailed 3D finite element (FE) analyses.

Offshore wind farm sites often consist of multiple soil layers, each with distinct geotechnical properties. To apply the PISA design model in layered soil conditions, soil reaction curves are first established through 3D FE calibration analyses for monopiles in homogeneous soil. These calibrated curves, corresponding to different soil layers, are then applied to layered conditions using an 'independent layer' approach, which assumes each layer behaves independently without accounting for interactions between adjacent layers [1]. These inter-layer interactions can significantly influence monopile response, potentially affecting design accuracy.

This study introduces a data-driven 1D design model [3, 4] that employs machine learning to define soil reaction curves. Unlike conventional methods, this approach enables direct calibration for layered soils, allowing a single calibration to account for various soil types and layering configurations. By calibrating the 1D model using soil reaction curves computed by FE analyses of piles embedded in layered soil profiles, the effects of layering are inherently incorporated. Additionally, this method accounts for spatial variations in layer thickness and soil properties across different offshore wind turbine locations within a wind farm, making it a versatile calibration tool for sites with similar layered soil configurations.

References

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Data-Driven 1D Design Model for Monopile Foundations in Layered Soils

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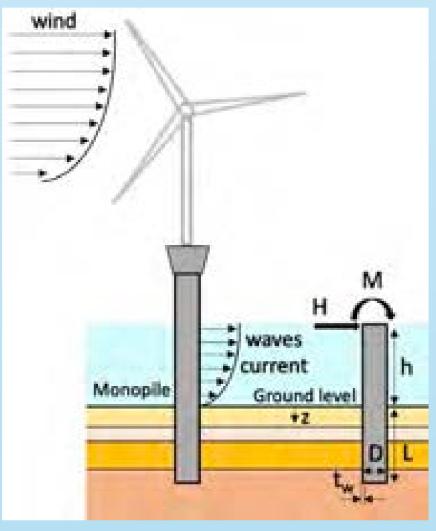
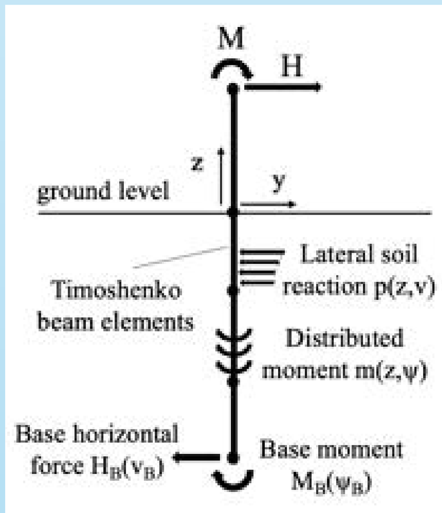
1.Introduction

The design of **monopile foundations** for offshore wind turbines (OWTs) is governed by **lateral loading** from wind, waves, and currents, generating large overturning moments.
Conventional design approaches model the monopile as a **1D beam with non-linear Winkler springs** but often **neglect interactions between adjacent soil layers in layered soils.**
Soil stratification significantly affects lateral response, and ignoring it can lead to inaccurate, conservative, or even unsafe designs.

Monopile Foundation [4]



Loads applied on the OWT substructure

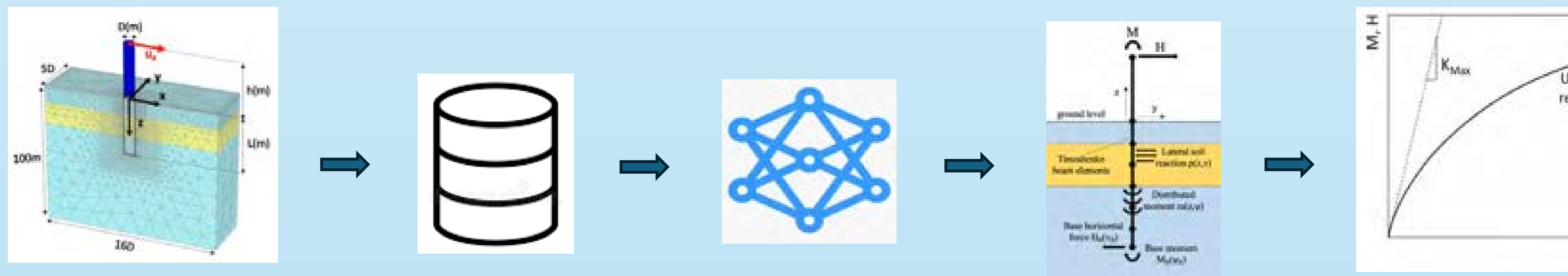


Pisa 1D FE Framework [2]

2.Objectives

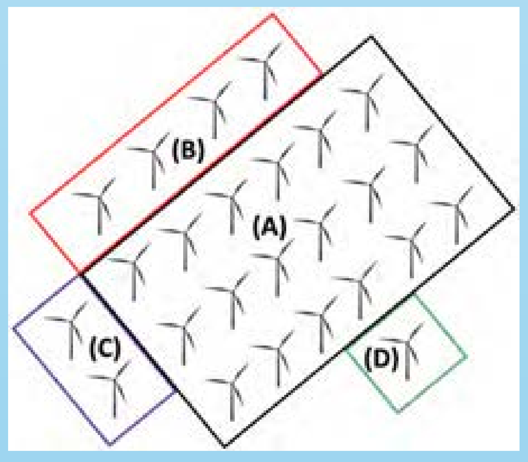
Develop a **1D model** to predict the **monotonic lateral response** of monopiles in **layered soils**.
Calibrate the 1D model using **soil reaction curve data** from layered soil analyses
Capture **layer-to-layer interactions** and enable **rapid site-wide predictions**.
Account for **variations in soil parameters** (e.g., strength, stiffness) and **layer thickness** across the wind farm.

Key stages followed to develop a data-driven 1D design model for layered soils

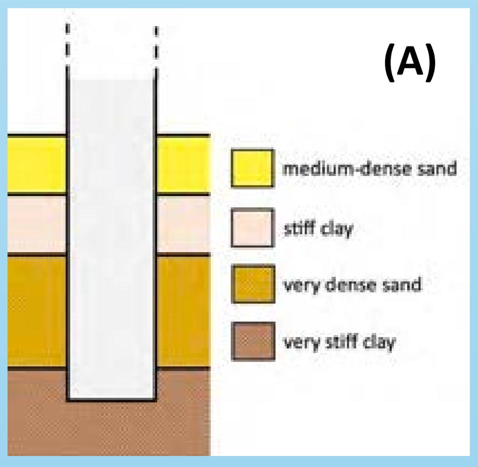


Calibration 3D FEA → **Soil reaction curves database** → **Machine learning model** → **PISA 1D framework** → **Prediction: Backbone curve**

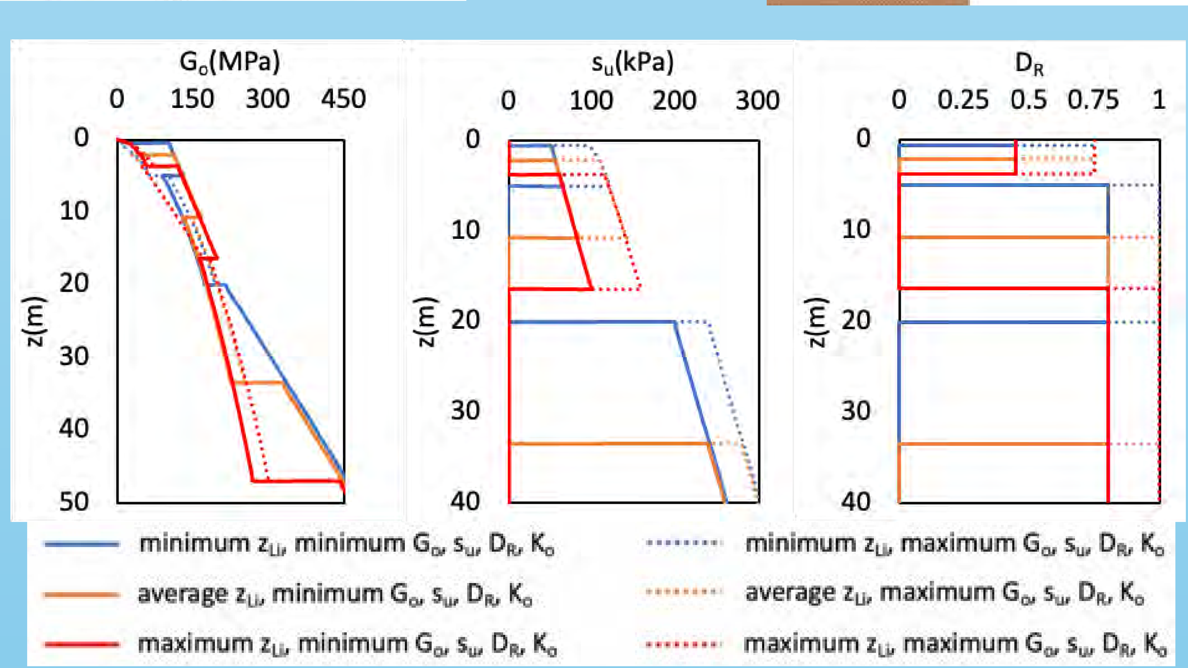
3. Site Investigation



Identify OWT locations with similar soil configuration



Analysed layered soil configuration

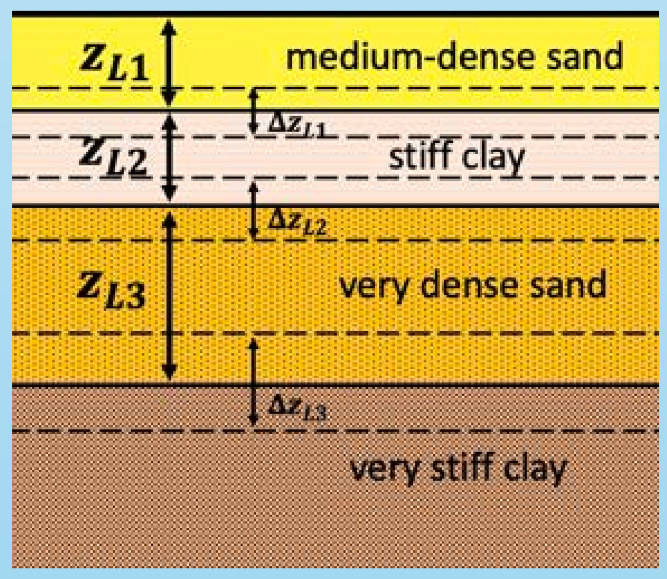


Identify site-wise soil parameters variation

4.3D FEA Calibration Analyses

Current Study Setup:
Software: PLAXIS 3D [1]
Clay Model: NGI-ADP
Sand Model: HS-Small

Identification & Calibration Process:
Parametrise the problem to reduce the number of required 3D FEA.
Define a calibration space to capture spatial variability across OWF:
Pile geometry
Soil parameters variation
Layer thickness range



Site Wise Variation in Layered Thickness for Configuration A

5. Soil Reaction Curve Database

For each calibration 3D FEA, the following soil reaction components are extracted:
1) Distributed lateral reaction **2)** Distributed moment **3)** Base horizontal force **4)** Base moment

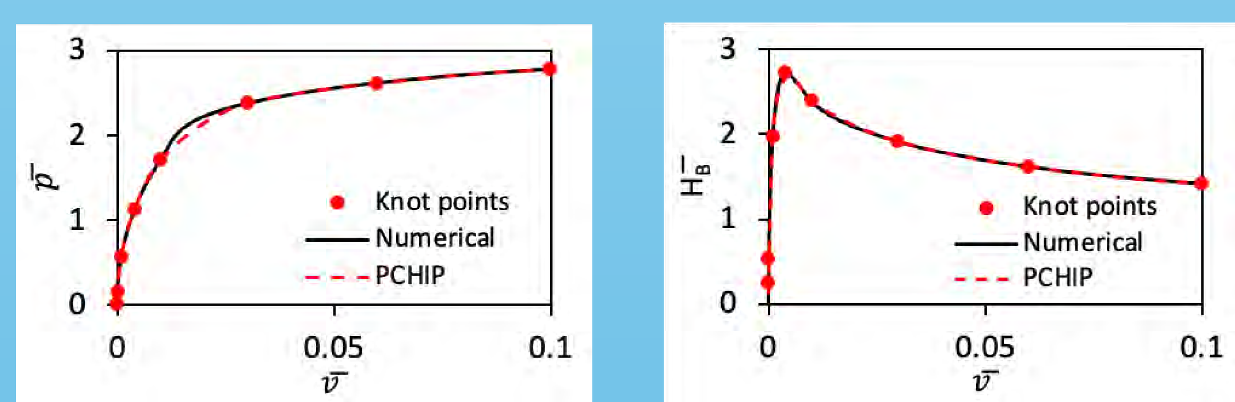
Soil reaction curves are normalised to a dimensionless form

Spline-Based Representation
Normalised curves follow: $\bar{y} = g(\bar{u})$
where: $\bar{u}$ = normalised displacement/rotation, $\bar{y}$ = normalised load/moment
Each curve is defined by 8 knot points, forming the basis of the data-driven model

knot-point parameters

$\bar{u}$	0	0.00004	0.0001	0.001	0.004	0.01	0.03	0.06	0.1
$\bar{y}$	0	$\bar{y}_1$	$\bar{y}_2$	$\bar{y}_3$	$\bar{y}_4$	$\bar{y}_5$	$\bar{y}_6$	$\bar{y}_7$	$\bar{y}_8$

A PCHIP interpolation scheme [3] ensures smooth transitions between knots.



PCHIP spline soil reaction curve for use in the data-driven 1D design model

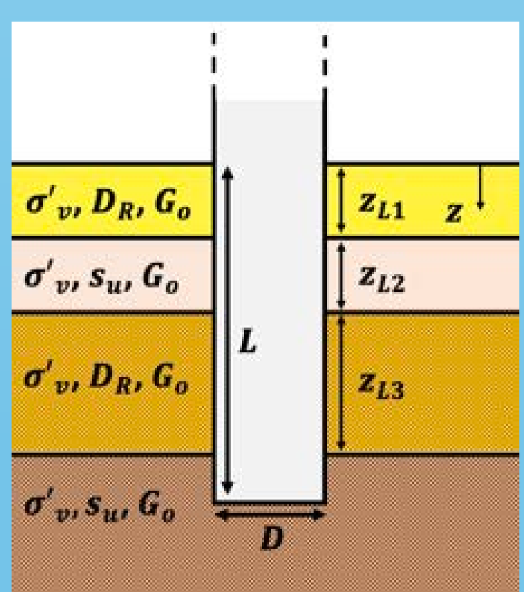
6. Training Features

(L/D): pile slenderness

(z/L): depth variation

(G_o/σ'_v), (s_u/σ'_v), (D_R): soil parameters

(z_{L1}/L): layer thickness



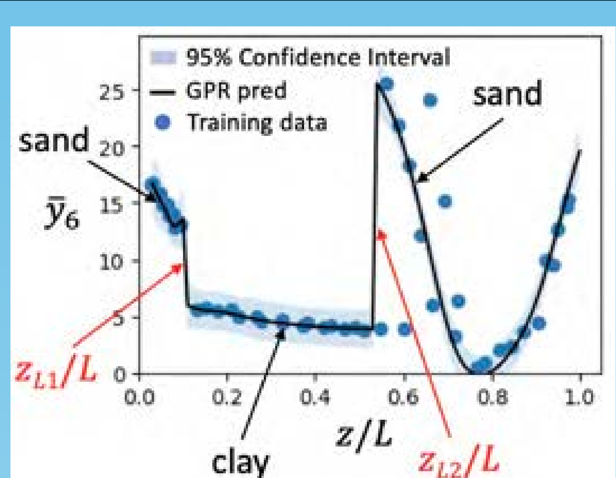
Layered Soil Configuration A

7. Machine Learning Model

A separate Gaussian process regression (GPR) model [5] is trained for each knot point in the spline.

GPR uses a zero mean function and a Matérn (v = 5/2) + White Noise kernel.

The dataset for each knot point is randomly split, with 80% used for training and 20% reserved for testing

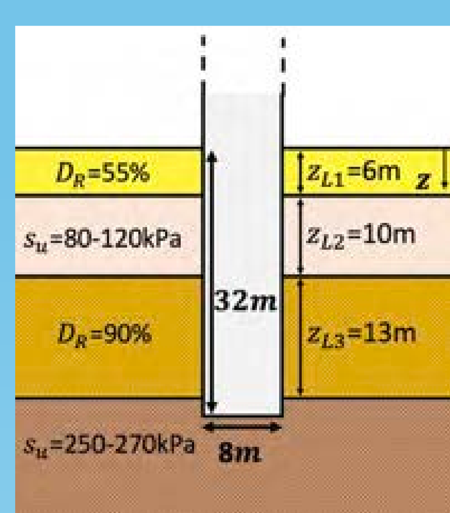


Example GPR outputs

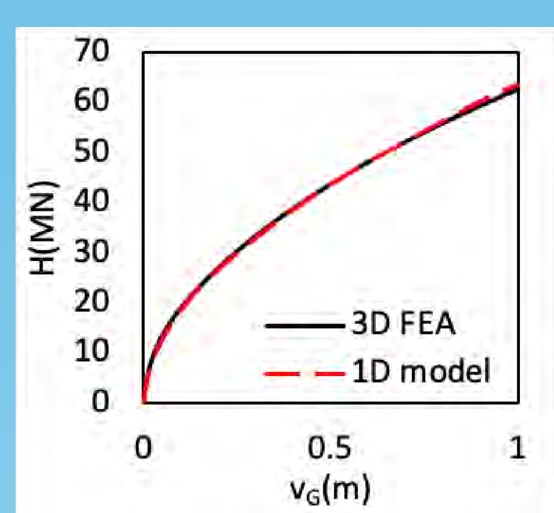
8. Design Scenario – 1D Model Predictions

1D model tested on unseen conditions:
Pile geometries
Soil parameters
Layer thicknesses

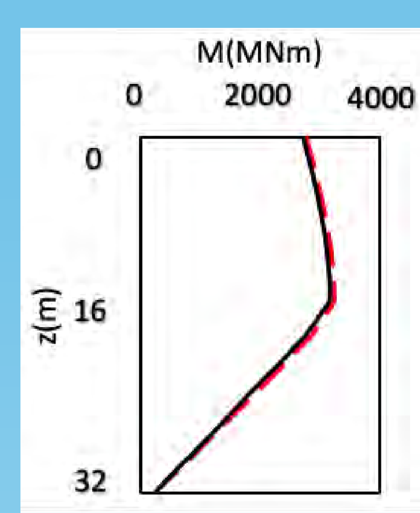
1D model prediction
Ground-level response:
Load–displacement
Moment–rotation
Bending moments profile



Design scenario



Load-displacement response



Bending moments profile

✓ Validated against 3D FEA – close agreement observed

REFERENCES:
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Academic Discipline: Electrical Engineering

Intelligent Fault-Tolerant Control of Offshore Wind Turbines via Deep Reinforcement Learning

Dr. Hongyang Dong1 and Dr. Shuyue Lin2

1 School of Engineering, University of Warwick, UK.

2 Department of Engineering, University of Exeter, UK.

Offshore wind turbines (OWTs) have clear advantages compared with their onshore counterparts, including extended installation areas and being capable of harvesting the highest-quality wind resources. Yet OWTs'development also faces new challenges, among which the faults in OWT operations have drawn extensiveattention, especially considering the fact that OWTs usually work under harsh environments in remote areasthat may lack regular overhaul. Under this context, fault-tolerant control (FTC) strategies for wind turbineshave aroused wide interest from both academia and industry. Proper FTC can ensure the reliability and safetyof OWTs under faulty conditions. This will mitigate potential operating risks, reduce operation & maintenancecosts, and extend the lifespan of OWTs. A reinforcement learning (RL) based fault-tolerant control strategyis developed in this paper for wind turbine torque & pitch control under actuator & sensor faults subject tounknown system models. An incremental model-based heuristic dynamic programming (IHDP) approach,along with a critic- actor structure, is designed to enable fault-tolerance capability and achieve optimal control.Particularly, an incremental model is embedded in the critic-actor structure to quickly learn the potentialsystem changes, such as faults, in real-time. Different from the current IHDP methods that need the intensiveeval- uation of the state and input matrices, only the input matrix of the incremental model is dynamicallyevaluated and updated by an online recursive least square estimation procedure in our proposed method.Such a design significantly enhances the online model evaluation efficiency and control performance,especially under faulty conditions.

Intelligent Fault-Tolerant Control of Offshore Wind Turbines via Deep Reinforcement Learning

Dr. Hongyang Dong[1] and Dr. Shuyue Lin[2]

[1] School of Engineering, University of Warwick, UK. [2] Department of Engineering, University of Exeter, UK

Abstract

Offshore wind turbines (OWTs) have clear advantages compared with their onshore counterparts, including extended installation areas and being capable of harvesting the highest-quality wind resources. Yet OWTs' development also faces new challenges, among which the faults in OWT operations have drawn extensive attention, especially considering the fact that OWTs usually work under harsh environments in remote areas that may lack regular overhaul. It is estimated that the costs induced by operation, maintenance, and component replacement for an OWT easily lead to a 20%-25% of annual profit drawdown. Under this context, fault-tolerant control (FTC) strategies for wind turbines have aroused wide interest from both academia and industry. Proper FTC can ensure the reliability and safety of OWTs under faulty conditions. This will mitigate potential operating risks, reduce operation & maintenance costs, and extend the lifespan of OWTs.

Methodology

- Handling actuator & sensor faults by deep reinforcement learning for offshore wind turbines (OWT).
- Combining the merits of both data-driven and model-based control methods.

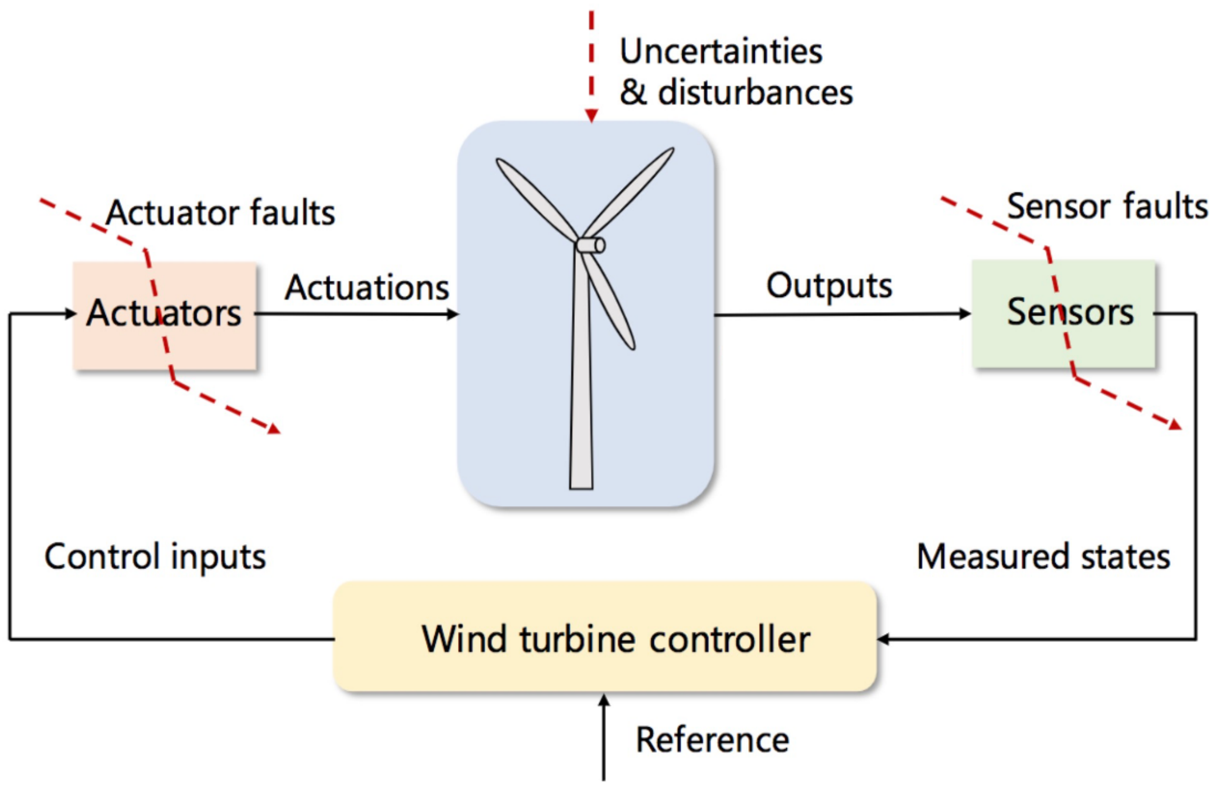

Figure 1. Offshore wind turbine control system with actuator and sensor faults [1].

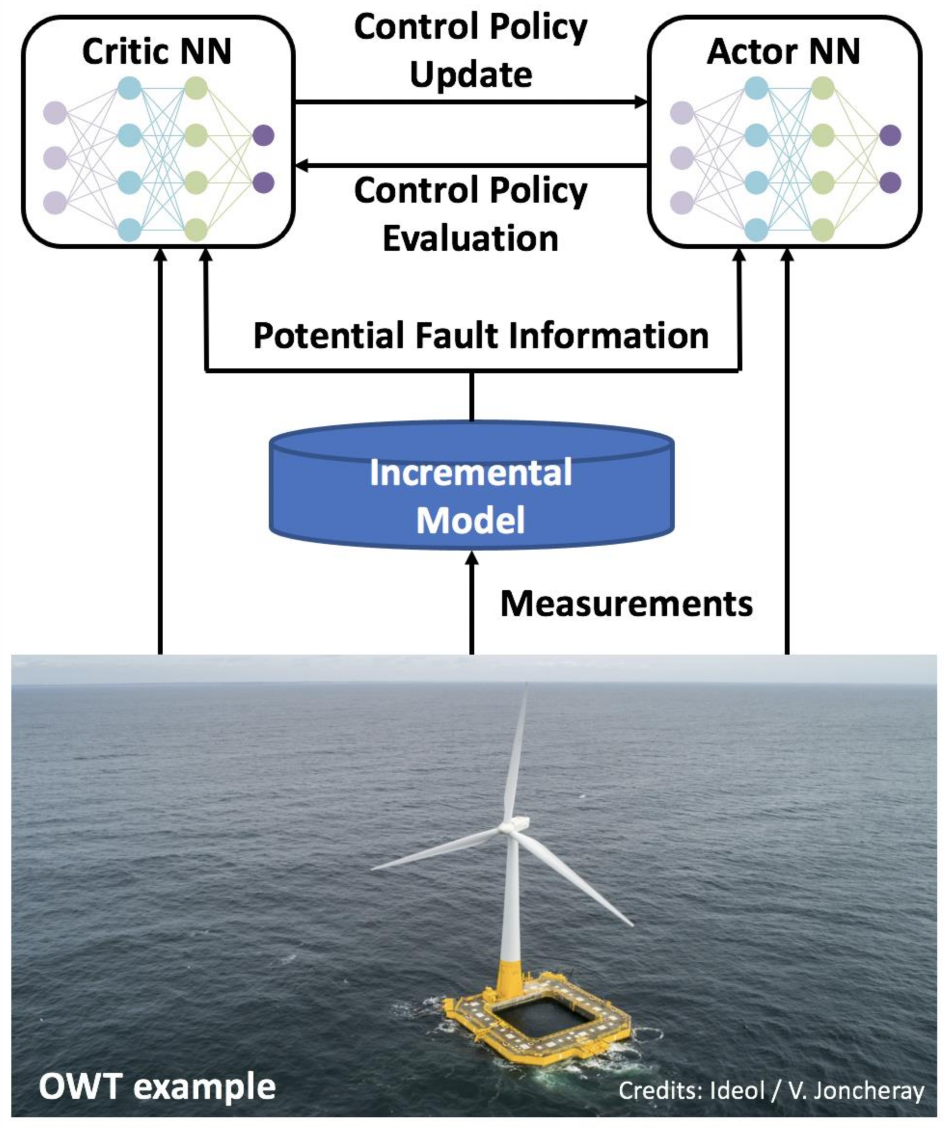

Figure 2. A brief illustration of the proposed control strategy [1].

Simulation and Discussion

- An incremental model to capture potential online system changes with real-time measurements.
- A critic-actor RL structure to achieve high-performance fault-tolerant control.
- Better performance than commonly-used methods (incl. PI and MPC) under faulty conditions.

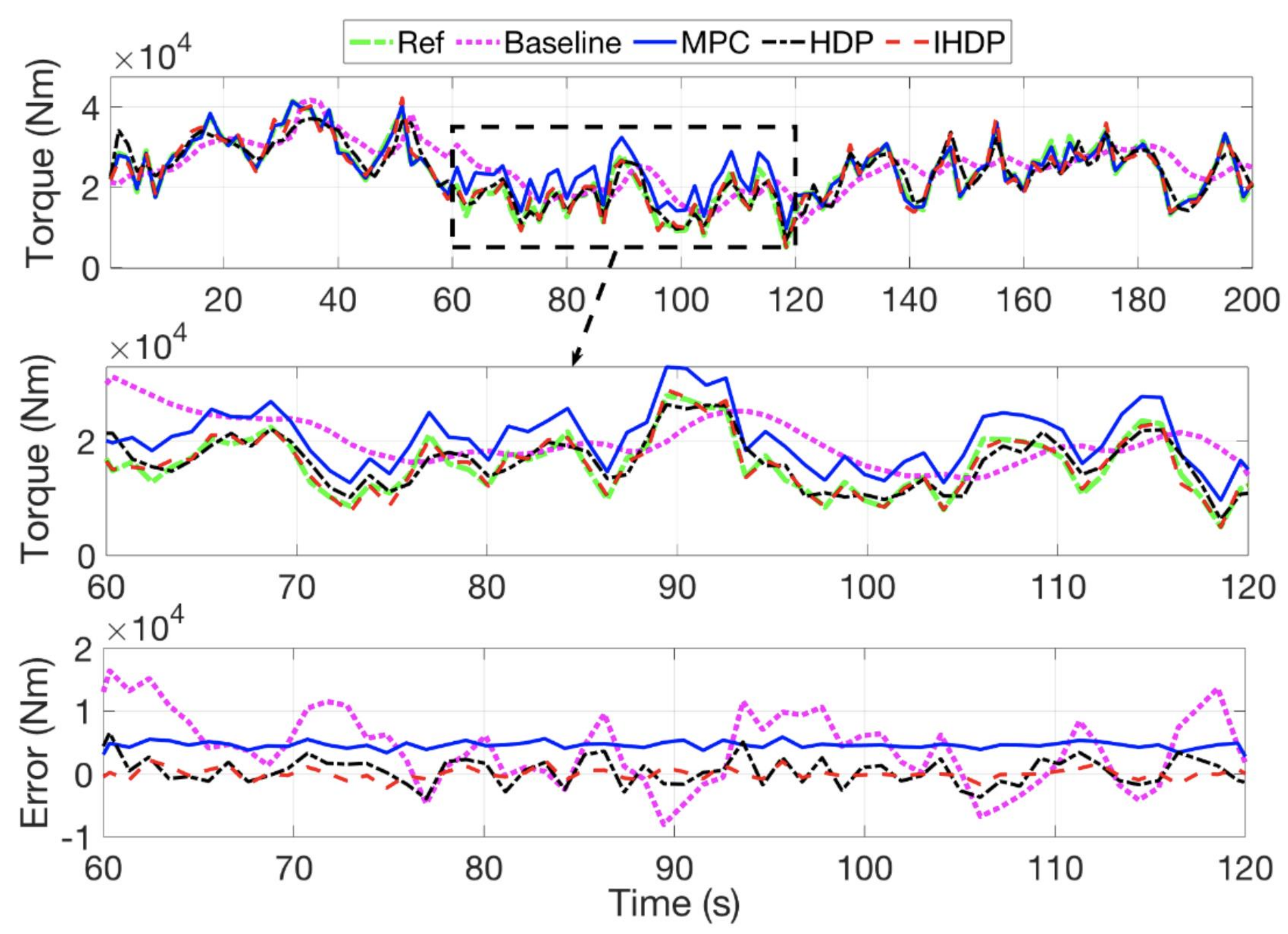

Figure 3. Generator torques under different controllers subject to the offset fault (+5000 N m) – IHDP is the proposed method, which leads to smallest errors [1].

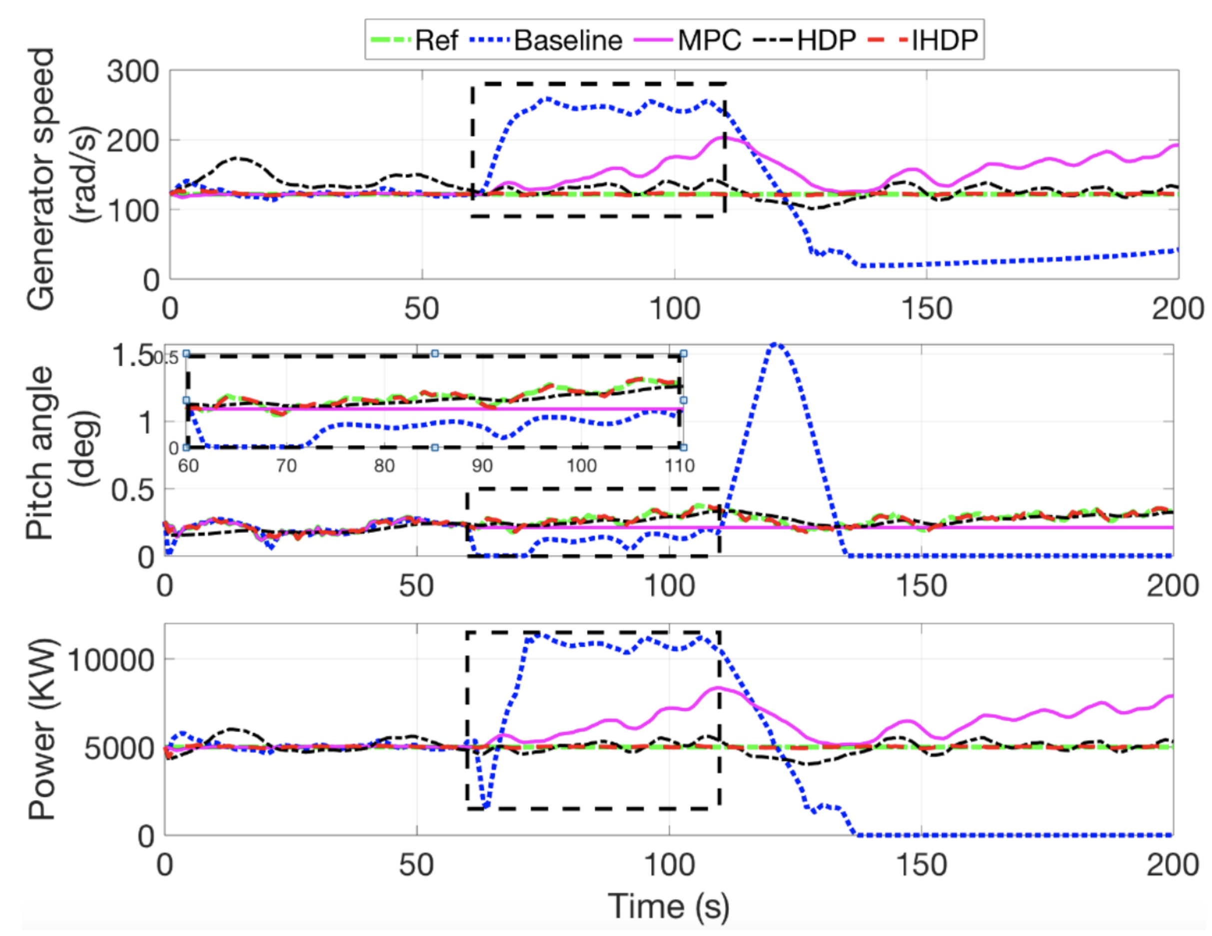

Figure 4. Control performance of different controllers under partial failure sensors and parameter uncertainties – IHDP is the proposed method, which leads to best performance [1].

Reference - [1] J. Xie, H. Dong, X. Zhao and S. Lin, "Wind Turbine Fault-Tolerant Control via Incremental Model-Based Reinforcement Learning," in *IEEE Transactions on Automation Science and Engineering*, vol. 22, pp. 1958-1969, 2025, doi: 10.1109/TASE.2024.3372713.

Adapting Building-Structure Bolt Design Practices for Offshore Wind Applications

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Abstract:

This study investigates the structural behaviour of bolted connections made using high-strength steel (HSS S690/S960) and stainless steel (austenitic/duplex grades) through 200+ experimental tests and 1,100+ finite element analyses. A fracture prediction framework integrating multi-axial stress parameters was developed to evaluate failure mechanisms in net section fracture, block shear, bearing, and tearout modes. The research assesses EN 1993-1-8 provisions for HSS and stainless steel connections, complemented by reliability-based safety factor calibration.

Key findings indicate that HSS materials demonstrate sufficient local ductility for stress redistribution despite relatively low ductility compared to mild steel and ultimate capacity in perforated plates is enhanced due to biaxial stress effects. Modified block shear design equations were proposed for HSS and stainless steel connections to address inconsistencies in current design rules. Furthermore, a correction factor was introduced to Cochrane's original equation to improve staggered bolt-hole design accuracy, particularly addressing gauge-to-hole diameter ratio effects. The research findings on HSS bolted connections were published in a support document for the latest version of Eurocode 3 (EN 1993-1-1) and Code of Practice for the Structural Use of Steel (2023) in Hong Kong.

In addition, a hybrid self-centring extended end-plate connection incorporating high strength bolts and two SMA elements (SMA Belleville washers and SMA bolts) was proposed. Experimental and numerical analyses of the hybrid connections demonstrated flag-shaped hysteresis with stable self-centring capability, moderate energy dissipation, and adaptable stiffness through preload controlling on SMA elements. An analytical model was proposed according to the component-based design framework given in Eurocode 3, which aligned well with test data, enabling practical moment-rotation predictions.

The established approaches validated in building structures offer extensible frameworks for adapting connection design practices to offshore wind applications, and marine environment validations require collaborative calibration. For example, the fracture model could enhance offshore bolted joints assessment and SMA hybrid principles may inform resilient connection designs for offshore wind turbine support structures.

Supergen ORE Hub Early Career Researcher Forum 2025

Adapting Building-Structure Bolt Design Practices for Offshore Wind Applications

University of Dundee

Xuemei Lin

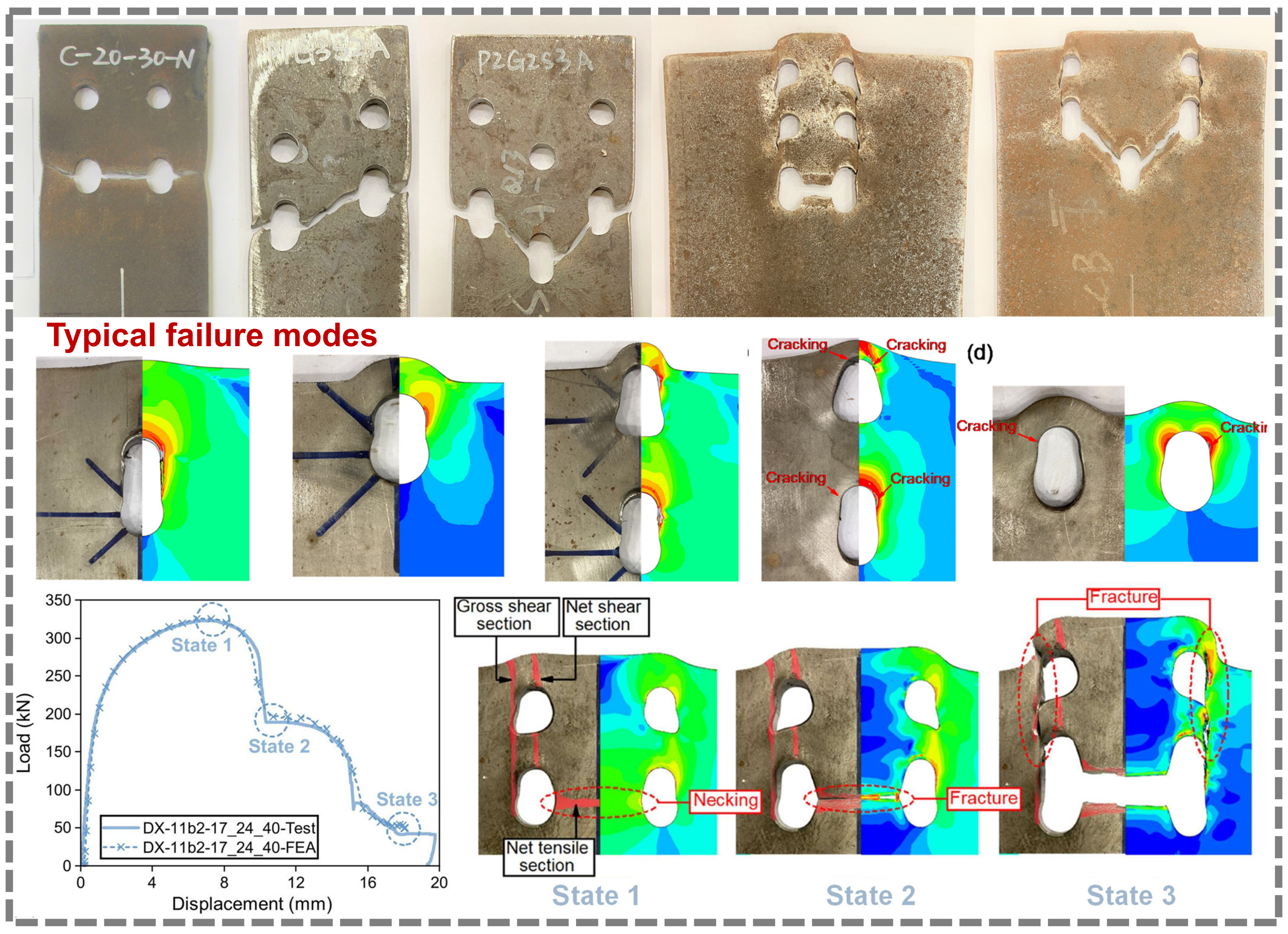
School of Science and Engineering, University of Dundee, UK

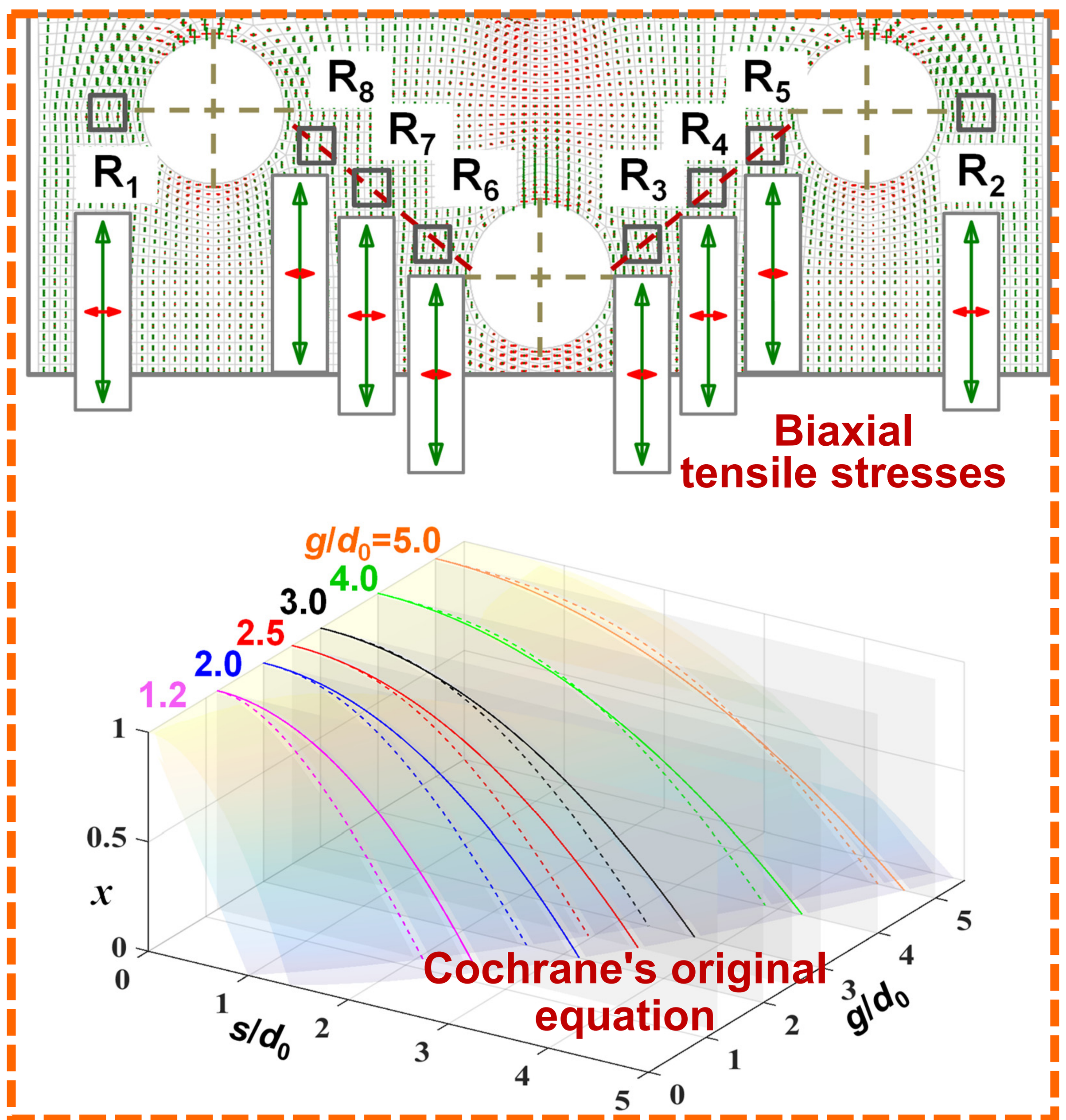
Introduction

This research investigates the structural behaviour of bolted connections through experimental and numerical studies on **high-strength steel** (HSS, S690/S960), **stainless steel** (austenitic/duplex), and **shape memory alloy** (SMA) hybrid systems. A comprehensive programme involving **200+ physical tests and 1,100+ finite element simulations** was conducted to assess the applicability of EN 1993-1-8 design provisions to HSS and stainless steel connections, complemented by reliability analyses to calibrate safety factors.

Key research outcomes (HSS & stainless steel bolted connections)

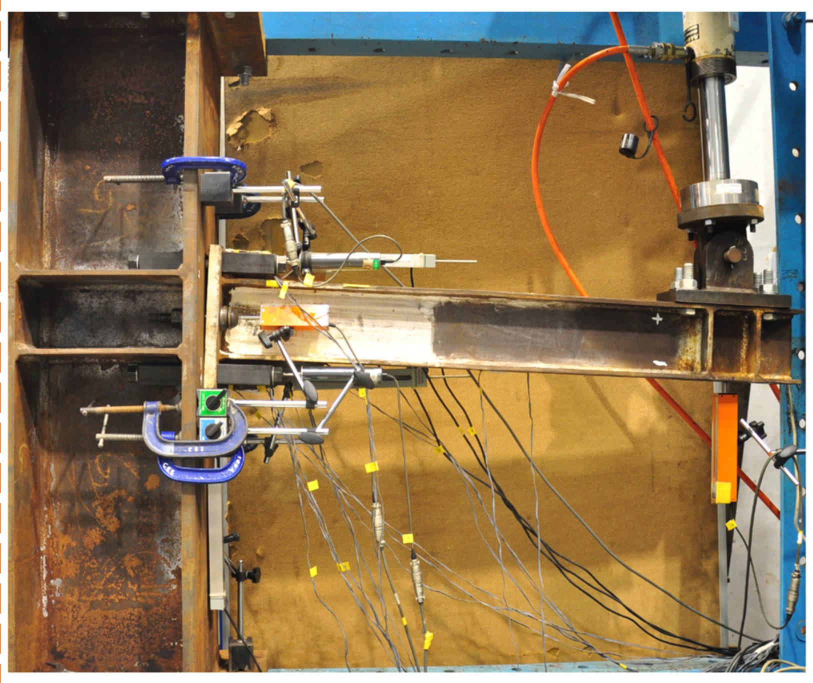
Test setup



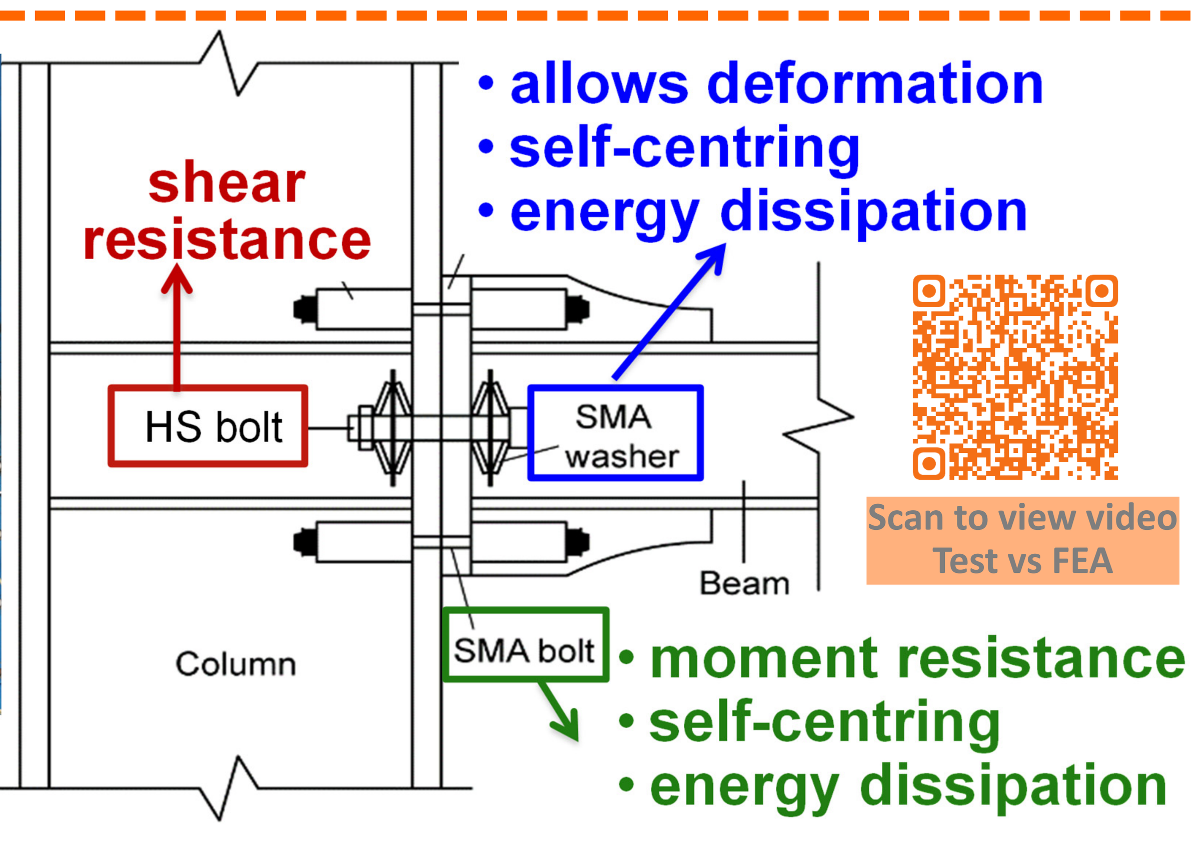


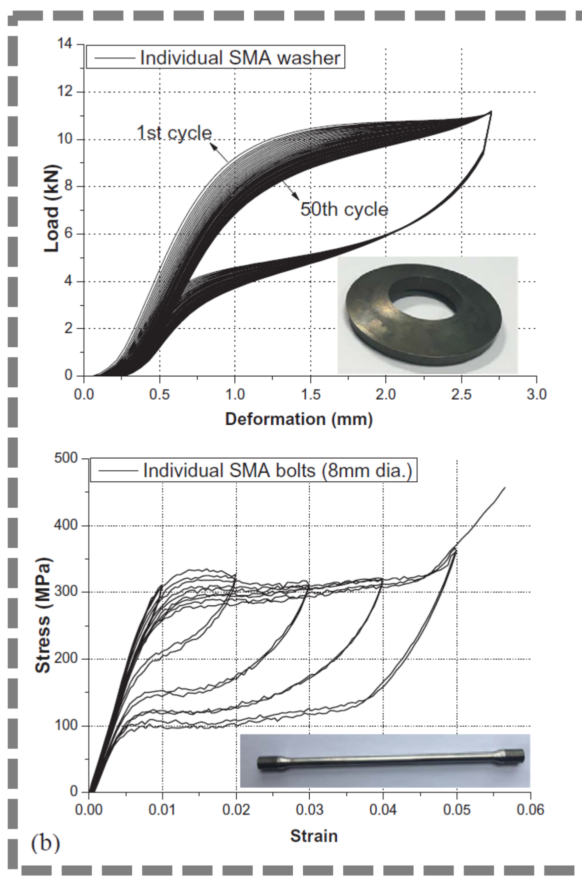
- Research findings of HSS connection were included in a technical report as a support document for the latest version of Eurocode 3 (EN 1993-1-1) and Code of Practice for the Structural Use of Steel (2023) in HK.

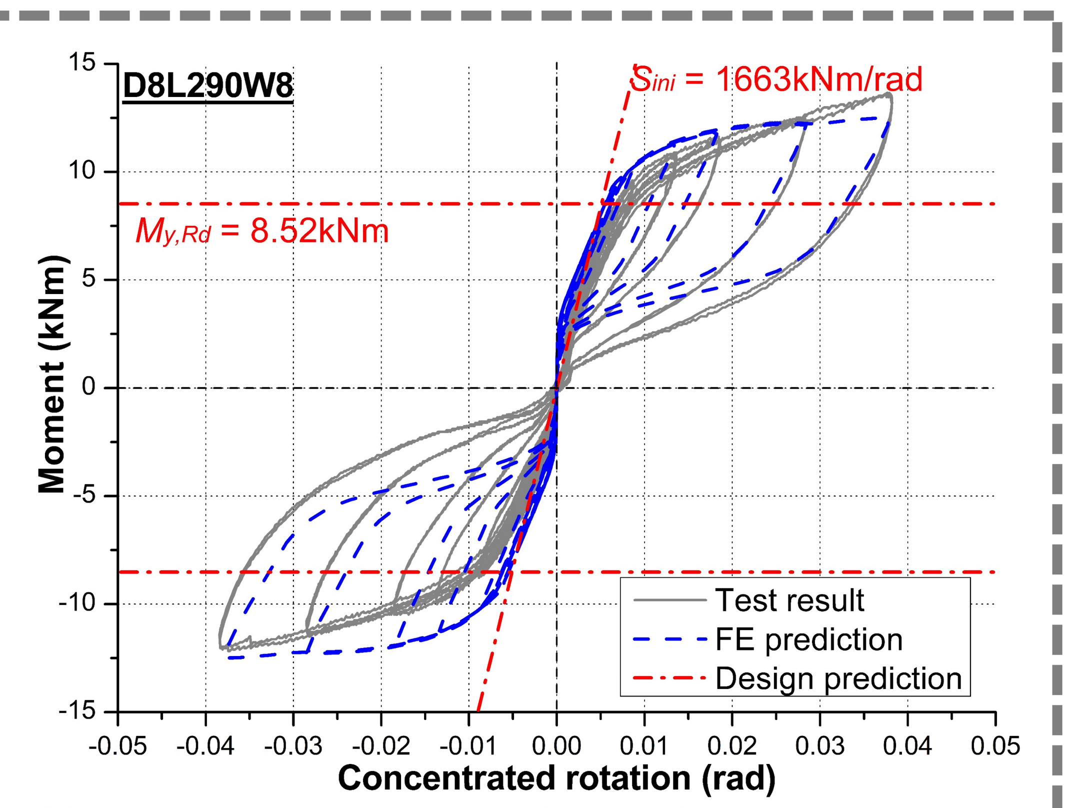
Key research outcomes (SMA-hybrid system)



Test setup







Moment-concentrated rotation responses

- The hybrid system demonstrated flag-shaped hysteresis with stable self-centring capability, moderate energy dissipation, and adaptable stiffness through preload controlling on either SMA bolts or washers.
- A component-based design model was proposed, enabling practical moment-rotation predictions.

Potential marine applications

- The established approaches validated in building structures offer extensible frameworks for adapting connection design practices to offshore structures applications, for example, the SMA hybrid principles may inform resilient connection designs for offshore wind turbine support structures, and marine environment validations require collaborative calibration.

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EUROCODES · The Hong Kong Polytechnic University 香港理工大學 · SCI Steel Knowledge · Supergen Offshore Renewable Energy · Tongji University · 國家鋼結構工程技術研究中心香港分中心 Chinese National Engineering Research Centre For Steel Construction (Hong Kong Branch)

Zaibin Lin, University of Aberdeen

Job Title: Lecturer

Academic Discipline: Civil and Mechanical Engineering

Floating Offshore Wind Turbines (FOWTs) require a multidisciplinary approach to optimize aerodynamic efficiency, hydrodynamic stability, and mooring system performance. This study presents a fully coupled numerical model of the National Renewable Energy Laboratory's (NREL) 5 MW OC4 semi-submersible FOWT, validated using Computational Fluid Dynamics (CFD) simulations in OpenFOAM and experimental data. The model accurately predicts the turbine’s aerodynamic response, platform motion, and mooring system behaviour under varying wind and wave conditions.

This research focuses on the impact of the centre of gravity (COG) height on FOWT stability and performance. Results indicate that reducing the COG height has a minimal effect on heave and surge motions but significantly decreases pitch motion and mooring line tension. This improves static stability, reduces wave load impacts, and enhances aerodynamic power output, leading to greater energy capture efficiency.

Additionally, the study compares the performance of a Conventional Mooring System (CMS) and a New Mooring System (NMS). Findings indicate that the NMS provides enhanced stability in surge and heave motions, distributes stress more efficiently, reduces mooring line tension, and improves structural durability. Although aerodynamic performance differences between the two mooring systems are minor due to phase differences in surge and pitch motions, optimizing these dynamics could further enhance energy generation and cost efficiency.

This research contributes to advancing FOWT technology by providing insights into optimising structural and mooring systems, ultimately improving offshore wind energy's reliability and economic viability. Future work will explore further refinements in mooring system designs and their integration into industry-standard analysis tools.

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Advancing Floating Offshore Wind Turbine (FOWT) Stability and Performance through Coupled Aero-Hydro-Mooring Analysis

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[b] State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, Dalian, China

[c] School of Engineering, University of Aberdeen, King's College, Aberdeen, AB24 3UE, the UK

Introduction

Context: FOWTs harness deep-sea wind energy but face challenges from coupled aerodynamic, hydrodynamic, and mooring dynamics.
Problem: Existing models often oversimplify interactions, limiting accuracy in predicting stability and efficiency.
Research Gap: Fully coupled simulations integrating real-world platform motions and mooring dynamics are computationally demanding and underexplored.

Objectives

1. Develop a **validated CFD model** for fully coupled aero-hydro-mooring analysis of FOWTs.
2. Investigate the impact of **Centre of Gravity (COG)** height on platform stability and energy capture.

Methodology

Tools: OpenFOAM-based CFD solver with:

turbinesFoam (Actuator Line Model for aerodynamics).
waves2Foam (wave generation/absorption).
MoorDyn (dynamic mooring system, Coulling et al., 2013).
sixDoFRigidBodyMotion (6-DOF platform dynamics).

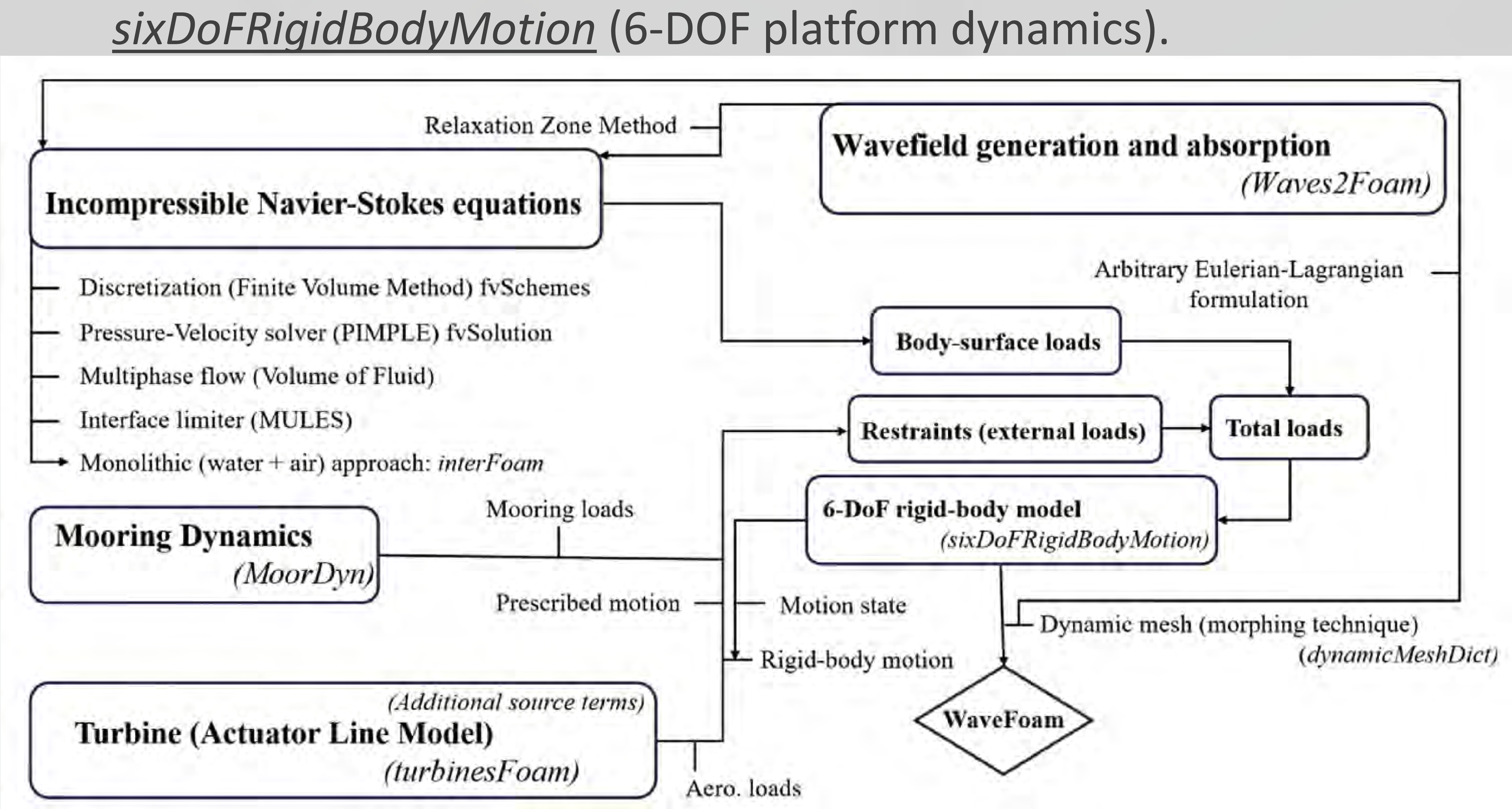
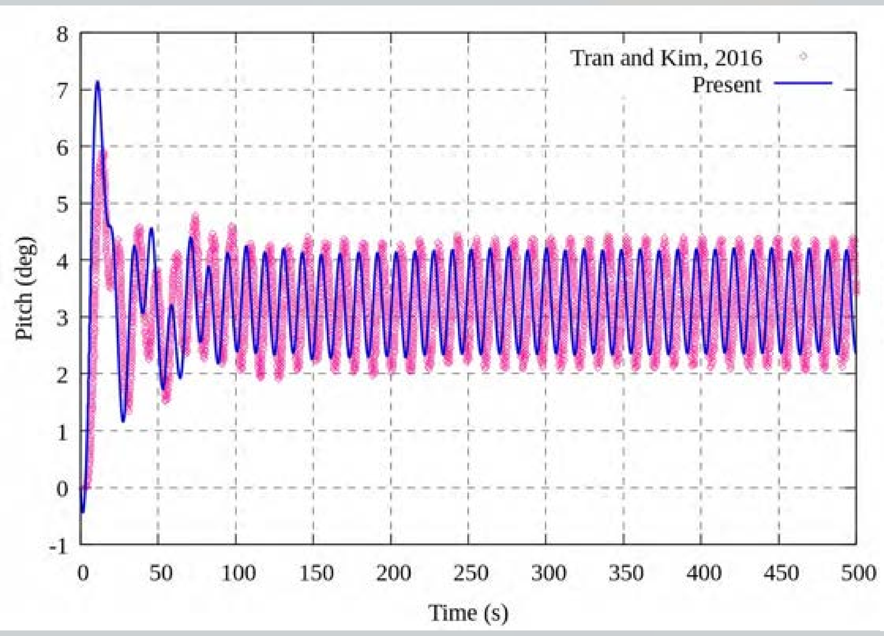
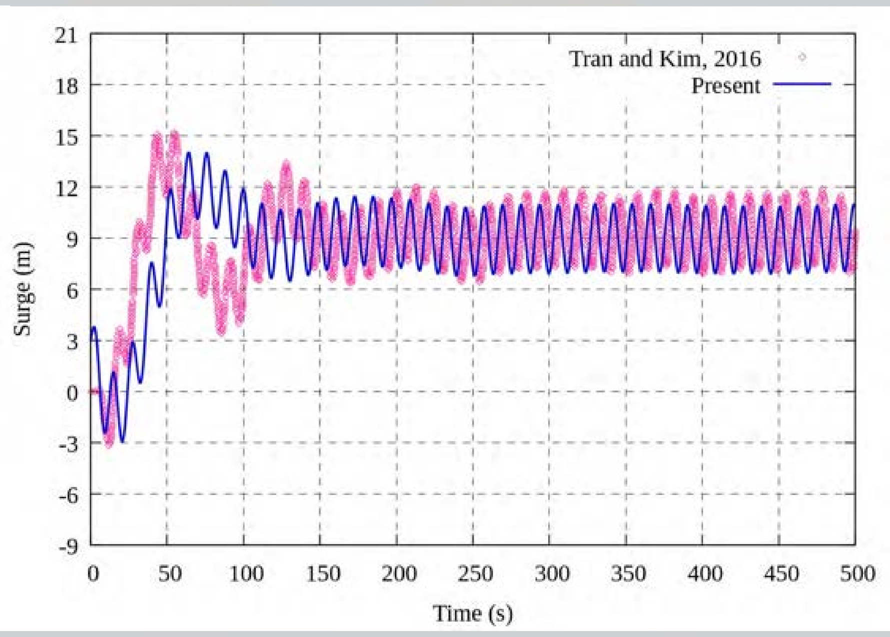


Figure 1: Flowchart of the FOWT fully coupled model

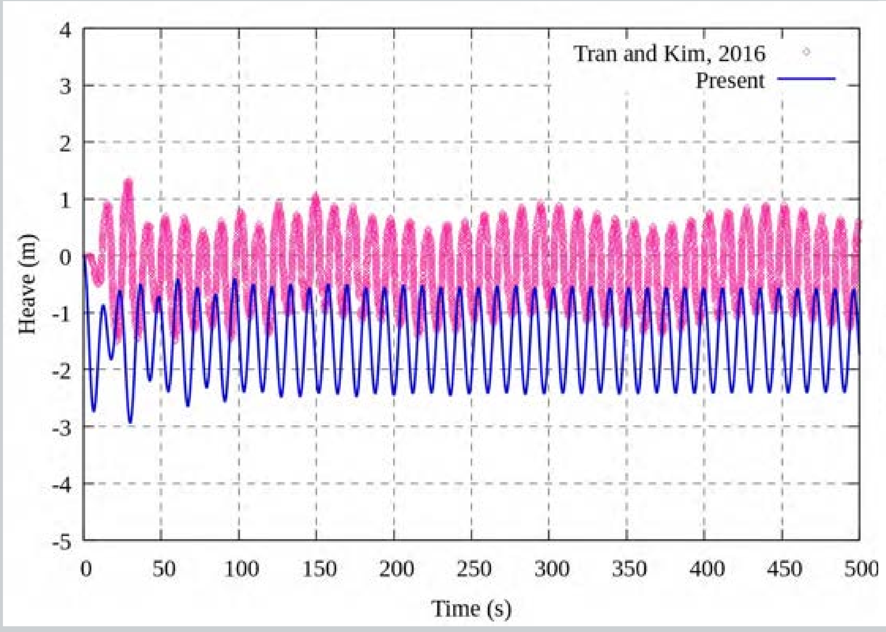
Model Validation: NREL 5 MW OC4 semi-submersible FOWT validated against experimental and numerical benchmarks.



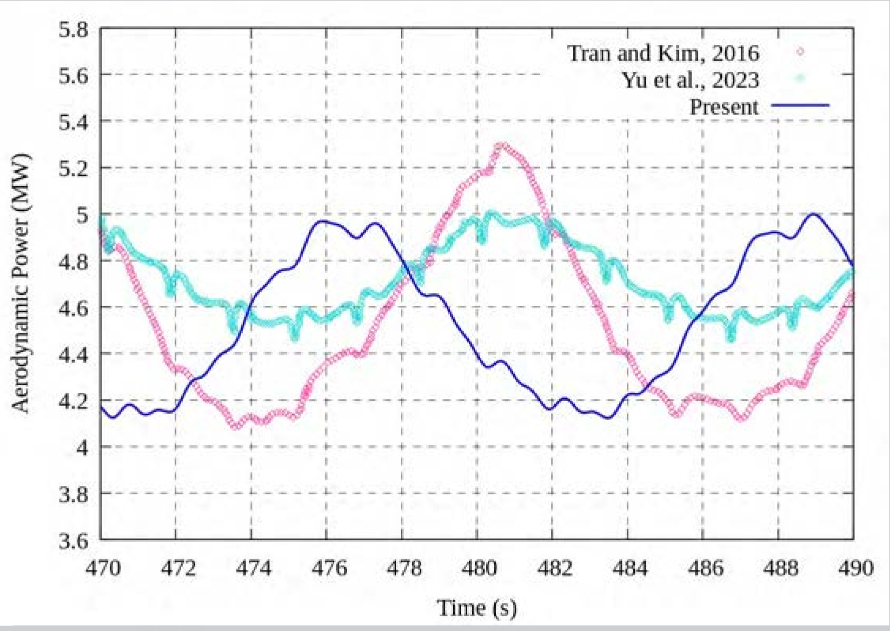
(a) Pitch response



(b) Surge response



(c) Heave response



(d) Power

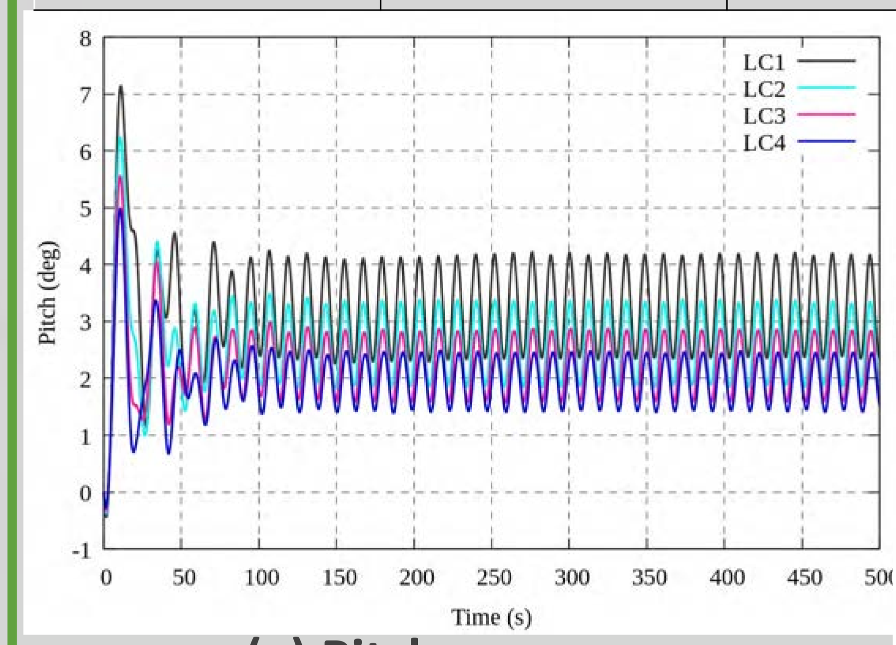
Figure 2: Comparisons for the platform motion response and power under the case LC1 in Table 1

Key Results

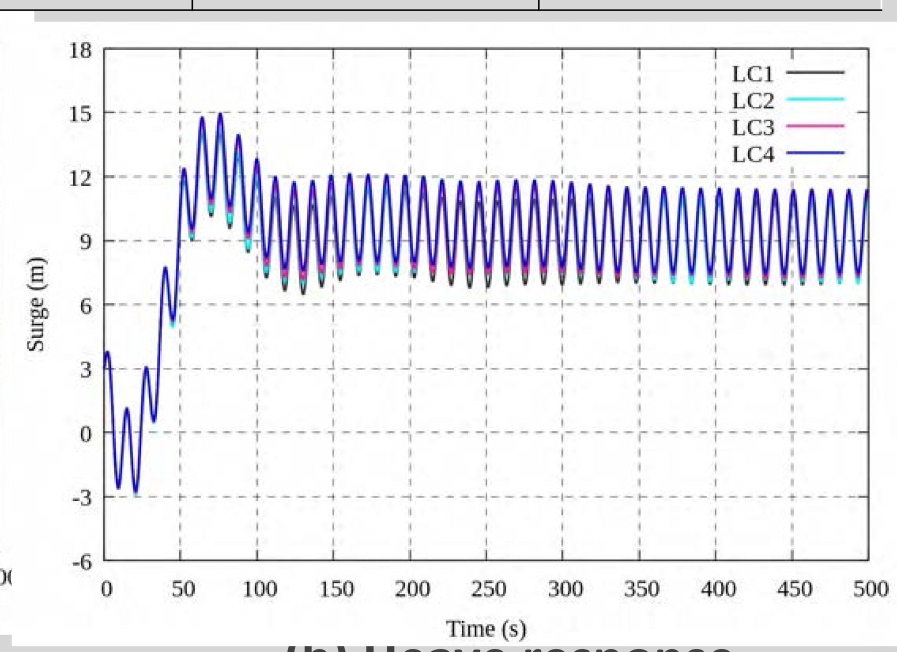
COG Impact: Lower COG reduces **pitch motion by 20%** and mooring tension by **8.6%**, improving FOWT stability but also fluctuating the power output.

Table 1: Environmental conditions and load cases for the FOWT

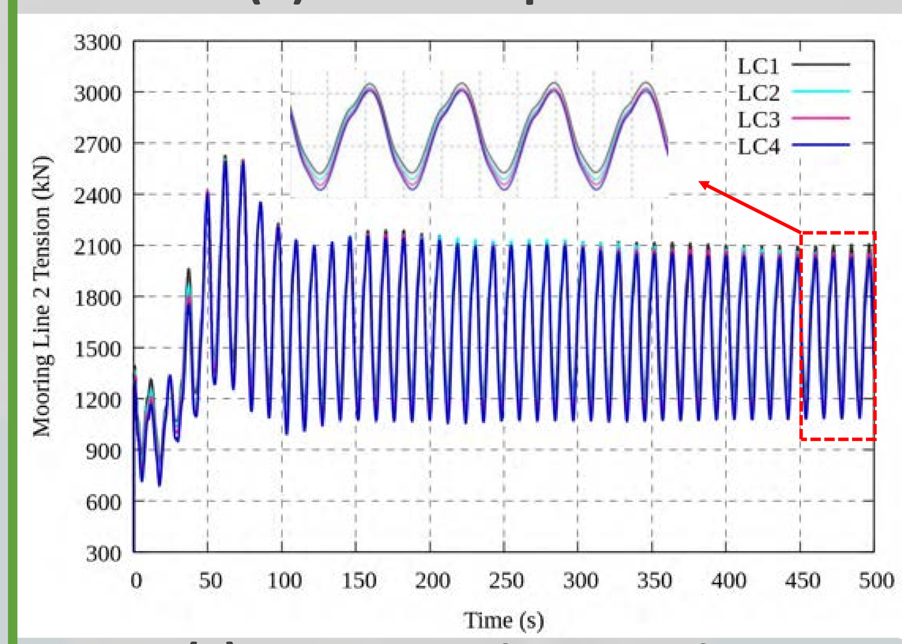
Environmental conditions				
Inflow Wind Speed (m/s)	Wave amplitude (m)	Wave Height (m)	Wave Period (s)	Rotor Speed (rpm)
11.4	3.79	7.58	12.1	12.1
Load Cases#				
COG (m)	LC1	LC2	LC3	LC4
	-10.2	-12.2	-14.2	-16.2



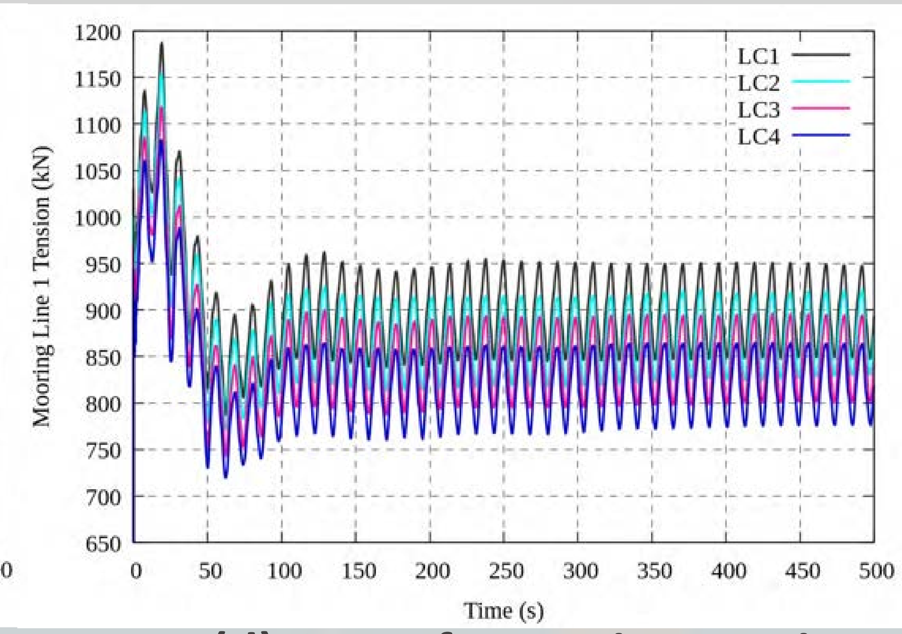
(a) Pitch response



(b) Heave response

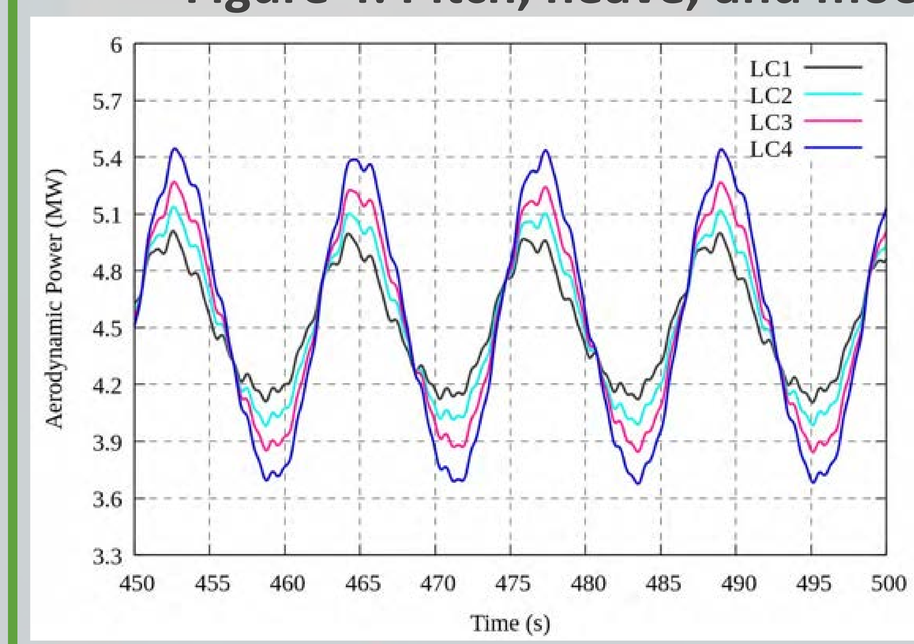


(c) Fore mooring tension

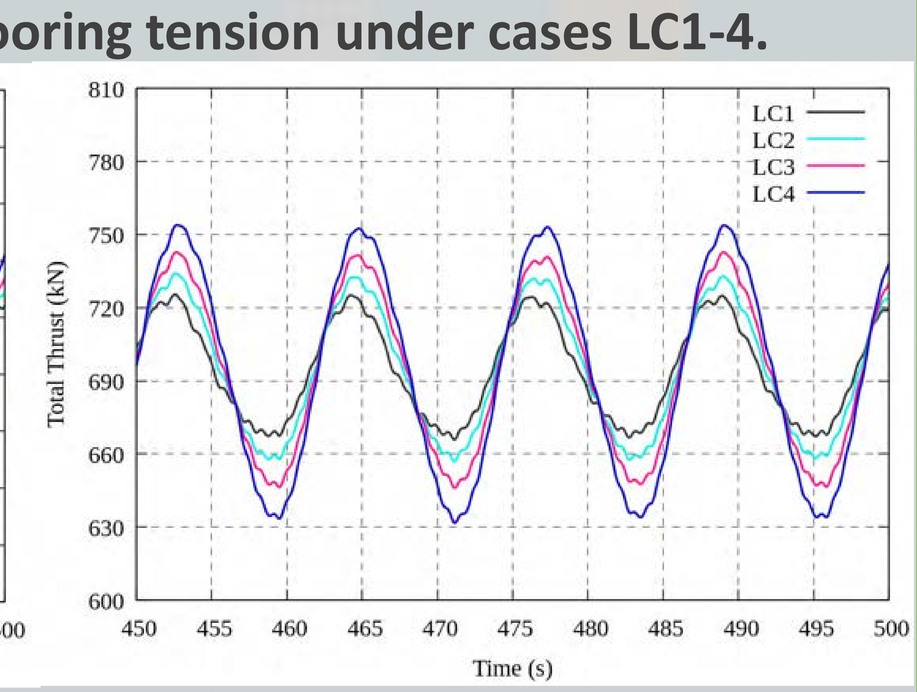


(d) Port-aft mooring tension

Figure 4: Pitch, heave, and mooring tension under cases LC1-4.



(a) Aerodynamic power



(b) Aerodynamic thrust

Figure 5: Aerodynamic power and thrust under cases LC1-4.

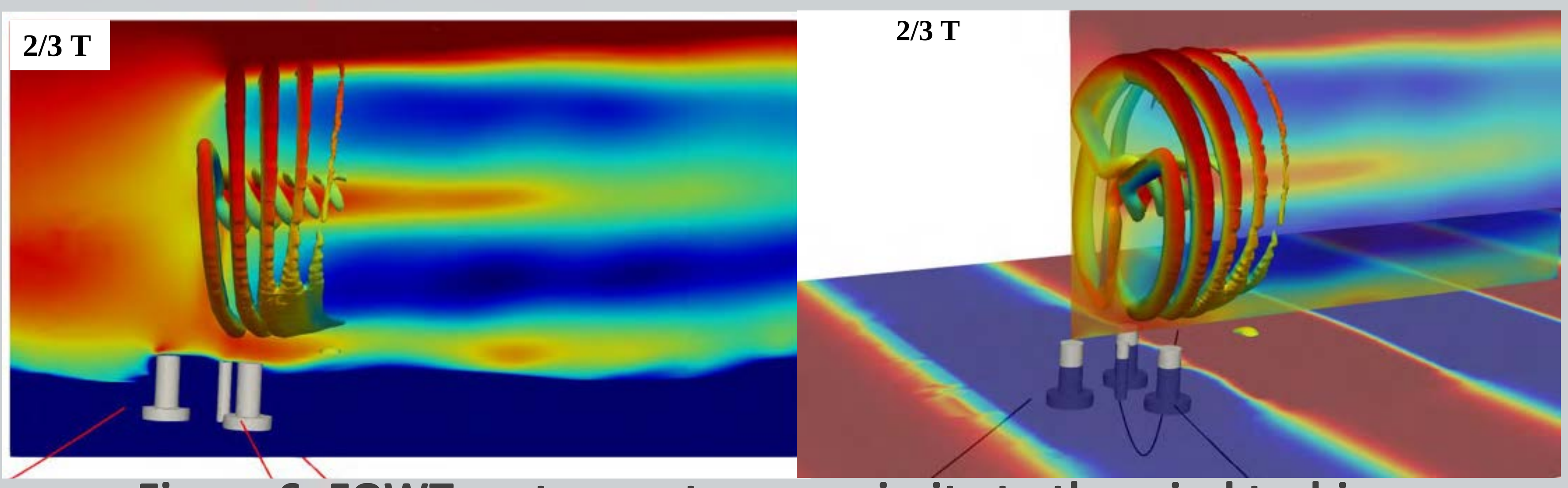


Figure 6: FOWT vortex contour proximity to the wind turbine and midplane flow field under the case LC1

Conclusion

The coupled model accurately predicts FOWT dynamics.
Reducing COG enhances the pitch and mooring tension of the FOWT system, but leads to fluctuations in power output.
Mean power output was increased by 0.9% due to improved platform stability.

Sponsor: UKRI Engineering and Physical Sciences Research Council; Supergen Offshore Renewable Energy; The Royal Society; HEC-WSI a High End Computing Consortium for Wave Structure Interaction

Personal website

Key reference

Haider et al. (2024). *Renewable Energy 237, 121793.*
Tran and Kim (2016). *Renewable Energy, 90, 204-228.*
Coulling et al. (2013). *J. Renew. Sustain. Energy 5, 023116.*

Origami-Enhanced Dielectric Fluid Generator for Wave Energy Conversion

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[3] Singapore Institute of Manufacturing Technology, A*STAR
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UNIVERSITY OF OXFORD
UNIVERSITY OF PLYMOUTH

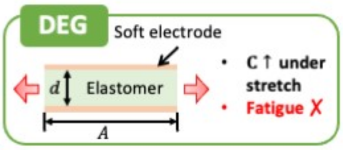
1 Introduction

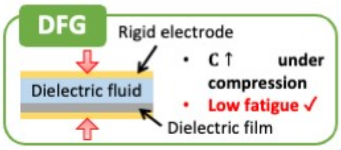
Ocean waves offer a vast, largely untapped, and sustainable energy resource. In the UK, wave energy has the potential to generate up to 30 TWh/year, about 10% of nation's electricity demand.

Dielectric elastomer generators (DEG) and dielectric fluid generators (DFG) use **mechanically variable capacitors** to convert wave motions into electricity. A parallel-plate capacitance is

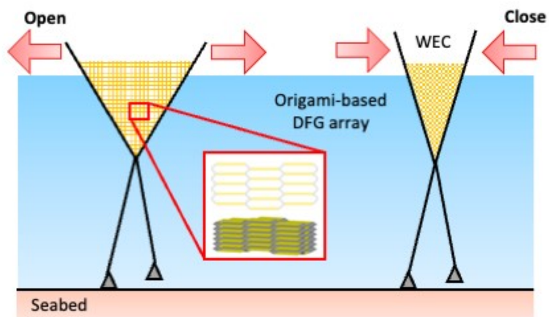
$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

where ε_0 is vacuum permittivity and ε_r is relative permittivity.



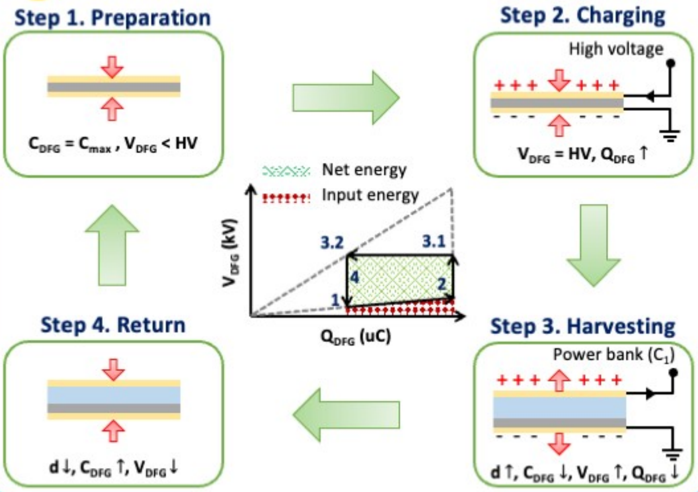


2 Why Origami?

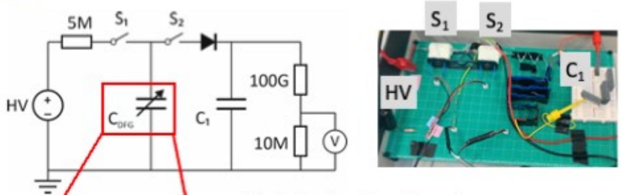


- ✓ **Easily stackable** for scalable arrays in wave energy converters.
- ✓ **Stress isolated to flexible joints** further enhances fatigue life.
- ✓ **Precise control** of electrode displacement improves efficiency.

3 DFG Working Cycle



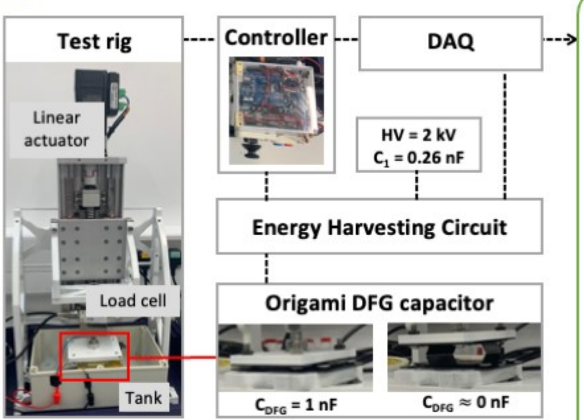
4 Circuit Design and Control



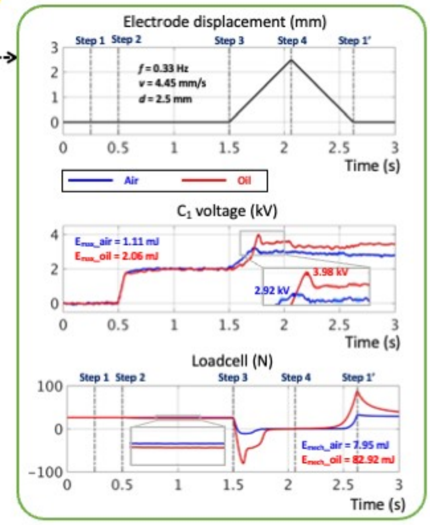
- Electrode size: 60 × 60 mm²
- Electrode material: copper and conductive silicone
- Dielectric film: polyimide ($\varepsilon_r \approx 3.1, E_{ds} \approx 200$ MV/m)
- Dielectric fluid 1: air ($\varepsilon_r \approx 1, E_{ds} \approx 3$ MV/m)
- Dielectric fluid 2: oil ($\varepsilon_r \approx 3, E_{ds} \approx 45$ MV/m)

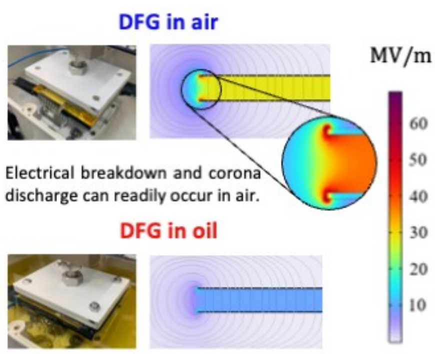
Step 1 ⇒ S1 and S2 open, high voltage (HV) on, DFG idle
Step 2 ⇒ S1 and S2 close, DFG is charged to HV
Step 3 ⇒ S1 opens and S2 closes, DFG upper electrode lifts up
Step 4 ⇒ S1 and S2 open, DFG upper electrode lowers down

5 Single DFG in One Wave Cycle



Actuation frequency (*f*) and speed (*v*) are tuneable to match wave dynamics. Electrode displacement (*d*) is precisely controlled.





The higher permittivity and breakdown strength of oil help prevent ionisation and suppress corona discharge, boosting output energy by 85.6%. However, its high viscosity increases mechanical energy demand per cycle, reducing conversion efficiency from 14.0% to 2.5%. Speed control can help improve efficiency.

We gratefully acknowledge support from the Supergen ORE Hub and Wave Energy Scotland for the Flexible Fund Project (FF2023-1041), and from EPSRC for the FlexWave Project (EP/V040227/1).

UKRI Engineering and Physical Sciences Research Council
Supergen Offshore Renewable Energy
wave energy SCOTLAND

Yabin Liu, University of Cambridge

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Academic Discipline: Fluid Mechanics

Controlling Tip Vortices with a Grooved-tip Design

Junchen Tan*, Ignazio Maria Viola †,and Yabin Liu ‡

Underwater turbomachinery, such as propellers and tidal turbines, faces significant challenges from blade tip vortices, leading to cavitation and noise. Building on our previous work on controlling tip vortices by employing permeable tips1, we propose a novel and practical design featuring multiple grooves at the tip of a wing extracted from a NACA 63415 hydrofoil, consistent with the profile of the Supergen Benchmarking Turbine blade tip 2. Experiments were conducted in a water tunnel at a Reynolds number of 30,000, employing streamwise and cross-flow Particle Image Velocimetry (PIV) to visualise and understand tip flow and vortical structures with and without the grooves. Lift and drag forces were recorded to assess the impacts of grooved-tip designs on the hydrodynamic efficiency of wings.

Streamwise PIV results show a significant velocity deficit in the tip vortex with the grooves, suggesting a mitigated pressure drop and lower cavitation risk. The underlying mechanism involves micro-jets generated inside the grooves interacting with the primary tip vortex. Cross-flow measurements suggest substantial suppression of the tip separation vortex and significant reduction of vorticity within the primary tip vortex core.

Downstream of the wing, analysis of the swirling strength and vorticity confirms reduced vortex intensity and increased vortex dimensions, and consequently, enhanced diffusion. Additional vortex parameter analyses, including circulation, viscous core radius, and vortex intensity, reveal that the grooved tips enlarge the vortex core radius without notably affecting its circulation. Lift force measurements indicate a slight increase in the lift coefficient with grooved tips, though the variations are within measurement uncertainties. These findings demonstrate that the proposed grooved-tip design is very effective for controlling tip vortices, and yet its implementation is remarkably simple.

In summary, our proof-of-concept experiments introduce a novel, practical, and passive design for controlling tip vortices. For tidal turbines, this has the potential to significantly mitigate concerns about blade tip cavitation and thus overcome the upper limit of the turbine's tip speed ratio. Therefore, our ongoing experimental campaign at FloWave applies this design to a model-scale tidal turbine, utilising the Lagrangian Particle Tracking Velocimetry technique to visualise tip flows and wake structures. This innovative design offers broad applications, ranging from green propulsion systems to sustainable energy harvesting.

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1Liu et al., arXiv preprint 2408.16418 (2024).
2Willden et al., Proceedings of the European Wave and Tidal Energy Conference 15 (2023).

Controlling Tip Vortices with a Grooved-tip Design

Junchen Tan, Ignazio Maria Viola and Yabin Liu*

* Email address for correspondence: yl742@cam.ac.uk

Background and Concept

Tidal turbine blade tips, which experience the highest flow speeds, are prone to tip vortices and the associated cavitation and noise issues. The increase of turbine Tip Speed Ratio (TSR) is beneficial to optimise the turbines' efficiency and energy output, however, the risk of cavitation and noise due to tip vortices caps the upper TSR limit. In addition, the blades are more vulnerable to cavitation erosions in the seawater environment when cavitation bubbles collapse, and the performance and durability of tidal turbines can be severely affected. Therefore, considerable attention must be paid to tip vortex cavitation to overcome the upper TSR limit, thereby, improving the turbine efficiency and enhancing power extraction.

Building on our previous work [1] on controlling the tip vortices through permeable treatment modelled by a confined porous zone at the tip, we propose and investigate a novel and practical tip design to mitigate tip vortices through grooves achieving an equivalent 2D permeability. A schematic diagram of the flow control approach on a tidal turbine blade is illustrated in Fig. 1. The proof-of-concept experiments were performed around a wing in a water tunnel at the University of Edinburgh, and we are testing the design on a model-scale tidal turbine in FloWave with Lagrangian Particle Tracking Velocimetry (PTV) technique.

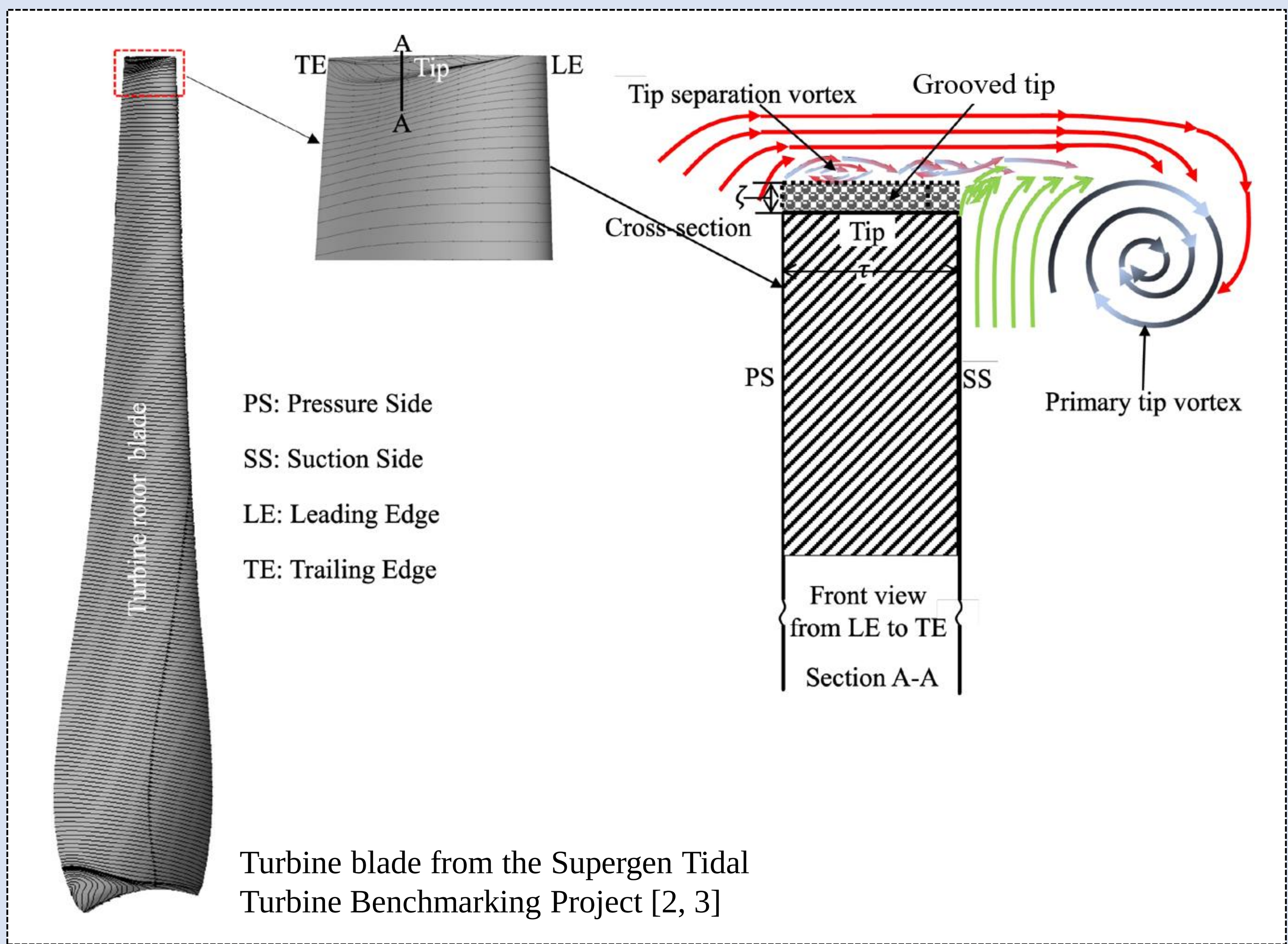

Fig. 1: Schematic of the flow control technique through a grooved-tip design.

Experimental Methodology

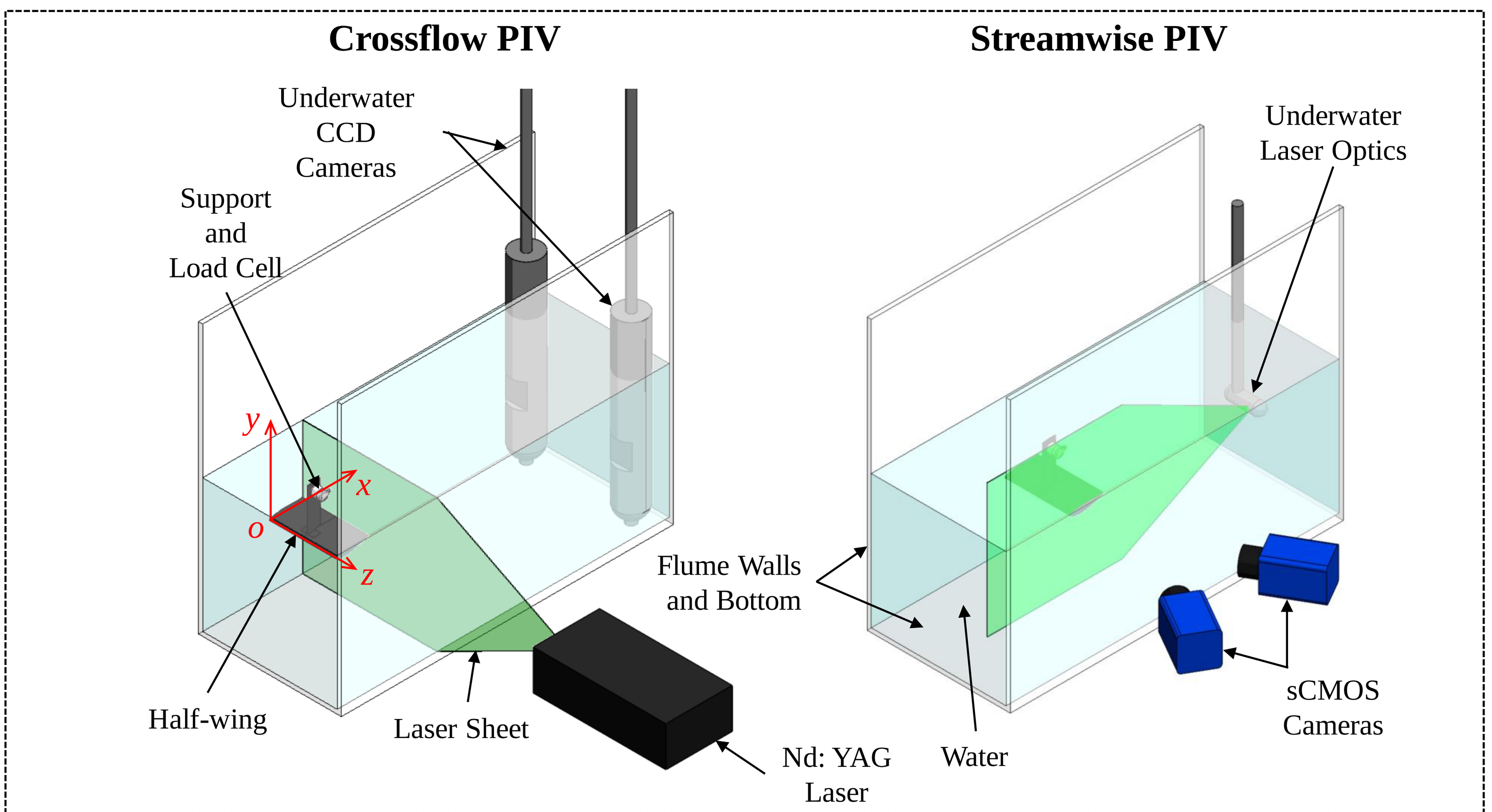

Fig. 2: Experimental setup for particle image velocimetry measurements.

Test parameters:

- ❑ Water tunnel experiment with crossflow and streamwise Particle Image Velocimetry (PIV) measurements (see Fig. 2).
- ❑ Freestream velocity $U_\infty = 0.3$ m/s; chord-based Reynolds number Re = 30,000.
- ❑ NACA63415, chord length c = 100 mm, span b = 200 mm, angle of attack $\alpha = 6°$.
- ❑ Groove depth at the tip is 1% of the wing span.

[1] Liu et al., 2024, https://doi.org/10.48550/arXiv.2408.16418.
[2] Liu et al., 2023, https://doi.org/ 10.36688/ewtec-2023-505.
[3] Willden et al., 2023, https://doi.org/10.36688/ewtec-2023-574.

Key Research Outcomes and Ongoing Work

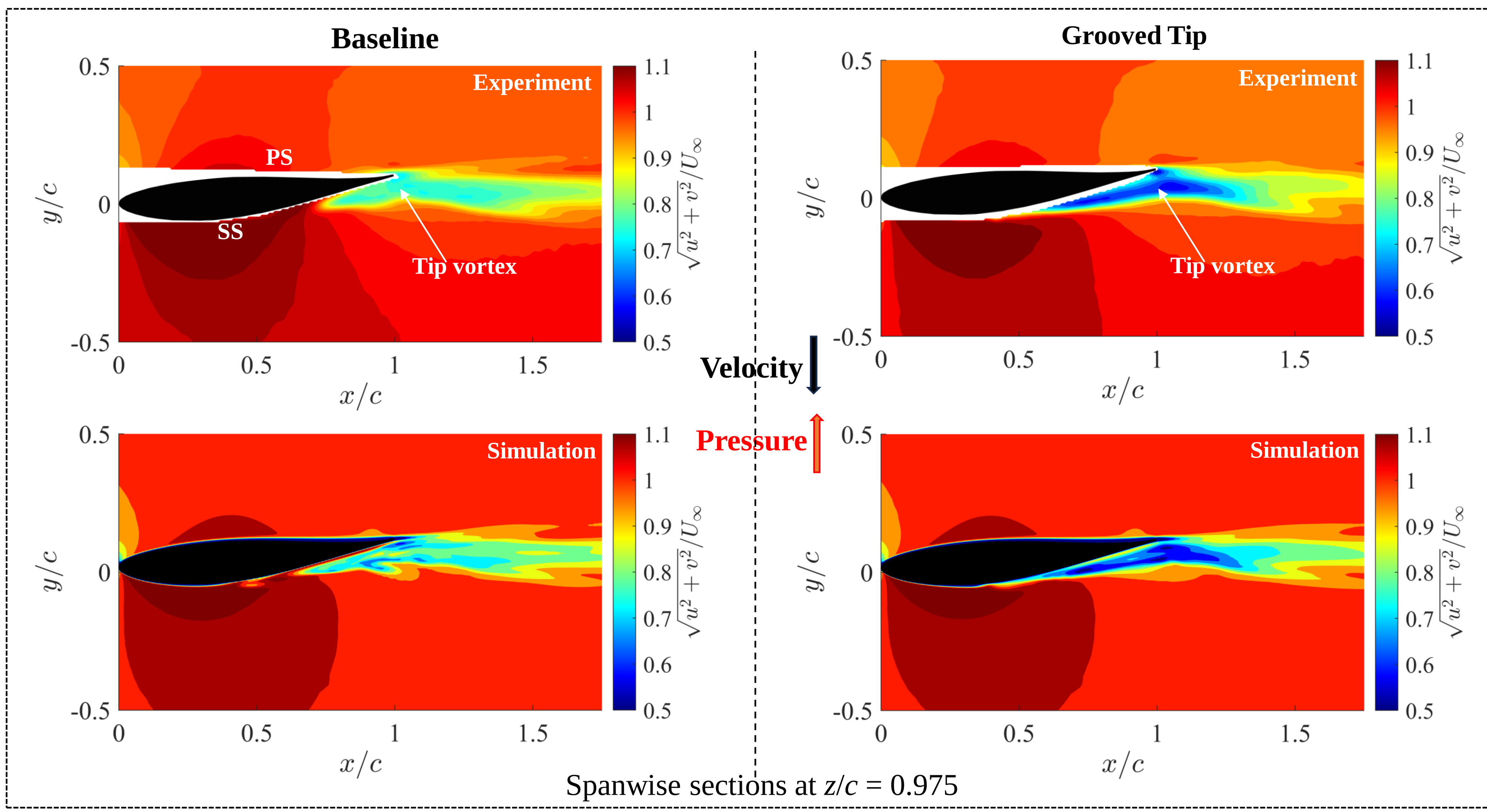

Fig. 3: Streamwise PIV results showing the velocity deficit in the wake with grooved tip.

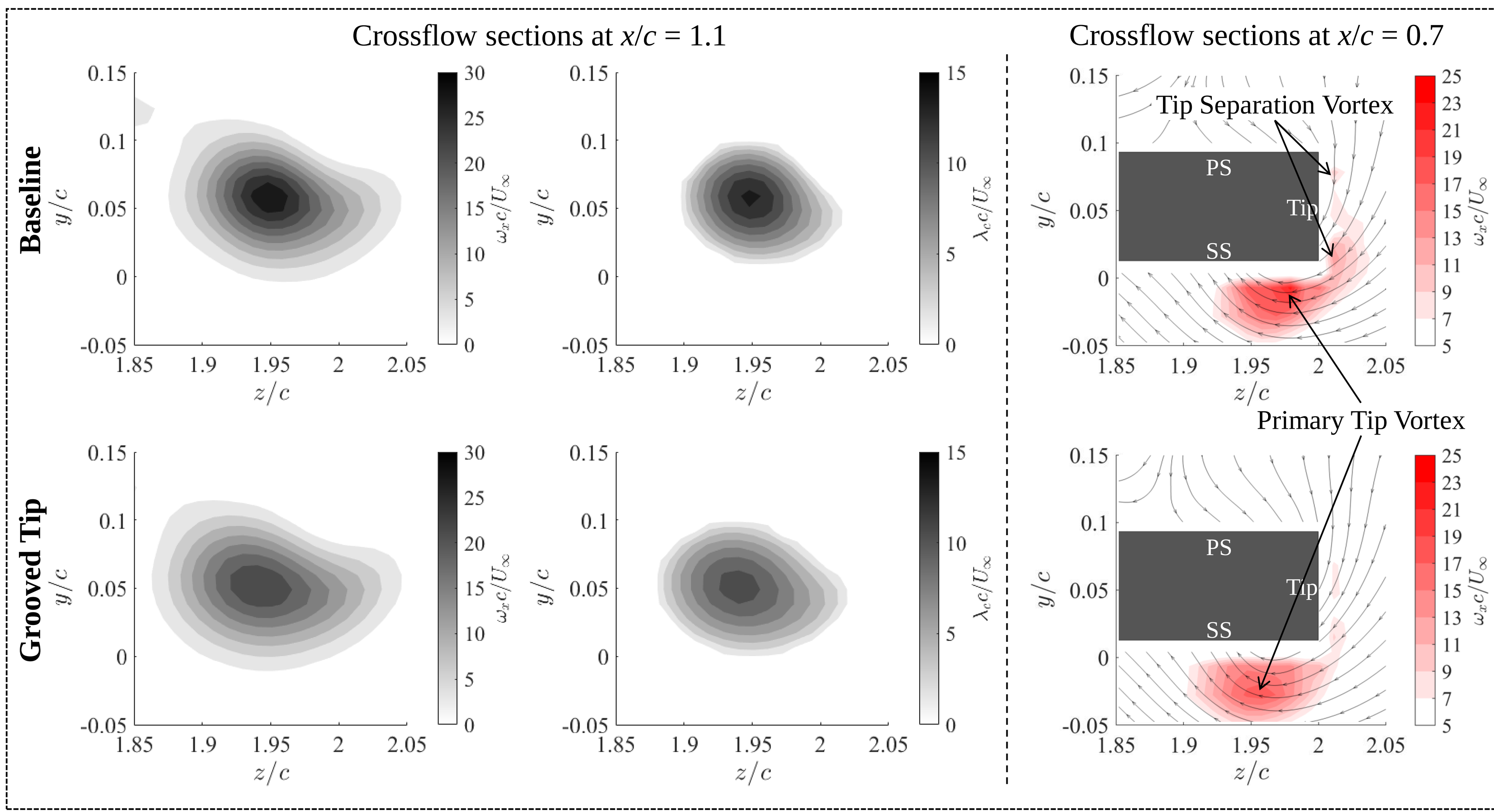

Fig. 4: Crossflow PIV results showing a reduction in vorticity (ω_x) and swirling strength (λ_c) in the wake with enlarged vortex dimensions (left panel); mitigation of tip separation vortex (right panel).

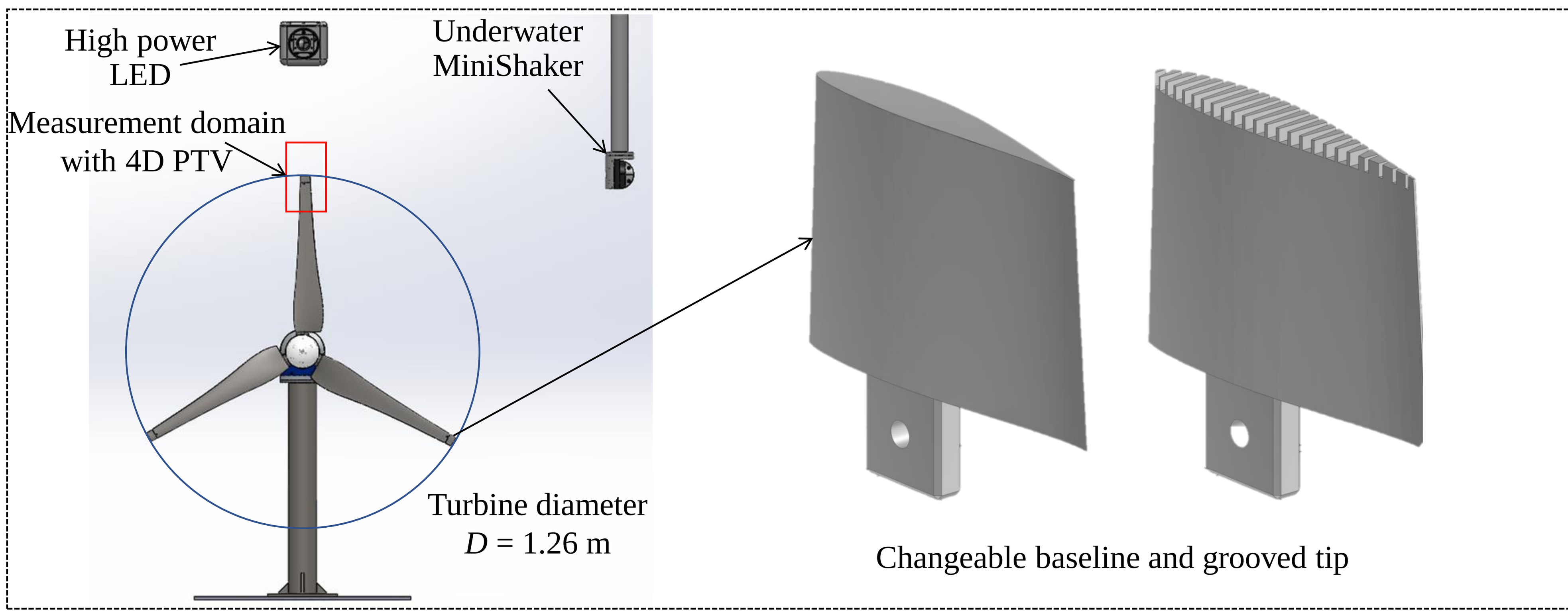

Fig. 5: Ongoing – turbine test with Lagrangian Particle Tracking (4D PTV) in FloWave (U. of Edinburgh).

Conclusions

- ✓ Controlling tip vortices through grooved tip design is experimentally tested in a water tunnel for a NACA63415 hydrofoil; the overall effect is promising.
- ✓ A velocity deficit is observed along the primary tip vortex trajectory, indicating the pressure drop within the tip vortex core is mitigated by the interactions between groove-jets and wake.
- ✓ The tip separation vortex on the foil tip is substantially suppressed.
- ✓ The underlying flow physics for the mitigation of primary tip vortex is through reduced vortex intensity and enlarged vortex dimensions.
- ✓ The design is effective, yet simple, as demonstrated by our proof-of-concept experiments. Model-scale turbine tests with Lagrangian Particle Tracking Velocimetry measurement will commence in April.

Acknowledgement: UK, EPSRC funded, Supergen Offshore Renewable Energy Hub [EP/Y016297/1] Flexible Funding, Royal Commission for the Exhibition of 1851 Brunel Fellowship, and The Royal Society ISPF-International Collaboration Award [ICA/R1/231053].