Supergen ORE Hub Third Annual Assembly (18 – 22 January 2021)

Early Career Researcher Poster Presentations - Abstract booklet

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Long Term Performance of Low Cost Motion Sensors

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Microelectromechanical system (MEMS) devices can provide low cost sensors capable of providing a variety of measurements in small packages. One of the many uses for these devices is to measure motion, typically using a combination of linear accelerometers, gyroscope and a magnetometer to form an Inertial Measurement Unit (IMU) integrated circuit. As part of work carried out under the SURFTEC project, four LSM9DS0 sensors were deployed as part of a data acquisition system on a floating tidal energy device. These sensors were used to track the motion of the device under different circumstances, as reported previously[1]

In order to use recorded magnetometer data to determine the direction of magnetic north, it is necessary to account for the effect of other magnetic fields and materials at the device's location. This can be done by rotating the device and fitting an ellipse (2D) or ellipsoid (3D)[2] to the recorded measurements. Figure 1 shows a subset of the calibration coefficients required to recover a correct heading from each of four sensors. This information shows that these low cost sensors are generally stable over days to weeks of operation, but are subject to sudden shifts in mean value. The shifts identified include events correlated across multiple sensors as well as events affecting only a single sensor.

In addition to these sudden, short term events, there are also longer term trends present. These may be due to sensor degradation or changes in local magnetic influences, which cannot be distinguished from the currently available data.

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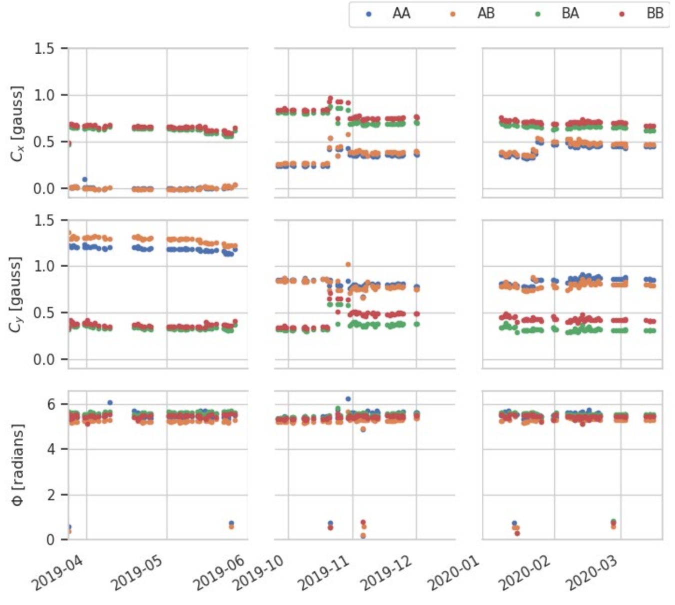

Figure 1: Subset of calibration coefficients required to recover 2D heading from MEMS magnetometers.

Coupled Modelling for Dynamic Submarine Power Cables – Interface Sensitivity Analysis of Global and Local Engineering Models

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Offshore wind farms are moving into deeper waters, where fixed foundations are not economically viable, forcing the development of floating wind turbines. At the end of 2017 there was 50MW of floating offshore wind installed globally, this is predicted to increase to around 30GW by 2030 [1]. Conventional power transmission cables are static and have been designed to operate in conditions that differ a lot from those experienced by cables for floating marine renewable energy converters. Dynamic cables are subject to greater levels of mechanical and electrical stress due to the motion of the platform in a highly energetic offshore environment. The combination of the different loads from waves, wind and currents, in shallower waters are more complex and need to be assessed through a combination of coupled numerical models and experimental tests – key to this is the verification of fatigue strength of the cable.

A dynamic power cable is susceptible to fatigue or over bend when there is an abrupt change in bending stiffness. The electrical capabilities of subsea cables are well understood; however, the structural capabilities are not. Previous work has shown that the local effects in the cable cross-section play an important role in the assessment of fatigue life. A good understanding of the internal structure of a subsea cable, and interaction between the layers, is integral to the development of robust and reliable, high voltage, dynamic, subsea cables.

Global analyses, assessing the overall motions of the floating platform, moorings and cables, are often carried out to provide data to inform the cable design process. Such analyses, however, are highly dependent on the input of local structural response coefficients which are available only through detailed local structural analysis numerically and/or experimentally. The local analyses are highly computationally intensive, and a balance needs to be struck. There is therefore a strong need to gain a better understanding of the local structural assessment of cable cross-sections and the coupling of the data attained through the local assessments with the global modal.

This work assesses a coupled FAST-OrcaFlex global model of the OC4 DeepCWind floating platform [2], moorings and 5MW NREL turbine [3], and incorporates a 66kV dynamic subsea cable, the structural properties of which have been determined through local structural analysis. The local model is initially informed with base input values from the global model, and then used to determine a range of bending and axial stiffness properties have been investigated, and the effect of altering these on the tension range and curvature of the cable when subjected to sea conditions representative to those at a floating offshore wind farm location.

The global model was run using regular waves for a duration of 11 minutes in real time, this took 30 minutes to solve using a laptop with 16GB RAM. The local model interrogated a simplified cable (core wires merged etc.), of length 1m, and took 10 hours to solve for a single structural stiffness value on a high-performance computer with 128GB RAM. Increasing wave height but holding cable properties constant had little effect on cable curvature (0.4%↑), but a large effect on tension range (271%↑). The global model is more sensitive to axial stiffness changes in the cable than bending stiffness changes, with a decrease in tension range of 38% and curvature of 28% when axial stiffness was doubled, for lower values of bending stiffness. Future work includes investigation of the sensitivity of coupled model to waves + swell from different directions, cable hysteresis, and friction coefficients between cable layers; assessing the fatigue performance of the cable and predicting cable life; and comparison of numerical modelling to experimental test results.

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Effects of POD Control on Offshore Wind Turbines Structural System

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This project investigates the effects power oscillation damping (POD) controller could have on the wind turbine's structural system. Most of the published work in this area has been done using relatively simple aerodynamic and structural models of a wind turbine which cannot be used to investigate the detailed interactions between electrical and mechanical components of the wind turbine. Therefore, a detailed model that combines electrical, structural and aerodynamic characteristics of a grid-connected Doubly Fed Induction Generator (DFIG) based wind turbine has been developed by adapting the NREL (National Renewable Energy Laboratory) 5MW wind turbine model within FAST (Fatigue, Aerodynamics, Structures, and Turbulence) code. This detailed model is used to evaluate the effects of POD controller on the wind turbine system. The results appear to indicate that the effects of POD control on the WT structural system is comparable or less significant as those caused by wind speed variations. Furthermore, the results also reveal that the effects of a transient three-phase short circuit fault on the WT structural system are much larger than those caused by the POD controller.

Structural performance and fatigue damage assessment for wind turbine blades based on the FSI model

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The FSI (fluid-structure interaction) model based on finite element methods becomes a fancy way to analyse the behaviours of the large wind turbines. Fatigue damage results in structural problems, which can be devastating to the blades and the wind turbine. Therefore, accurate FSI modelling and fatigue damage model of wind turbine blades are crucial in the fatigue assessment of large blades. In this study, an FSI model for wind turbine blades at full scale is established for the performance of the blade in the wind field. The aerodynamic loads are calculated using a CFD (computational fluid dynamics) model, and the blade structural responses are investigated using an FEA (finite element analysis) model. The interface of the FSI model is based on a one-way coupling, and aerodynamic loads calculated from CFD modelling are mapped to FEA modelling as load boundary conditions. The structural response is implemented to the nCode and fatigue damage model to predict the damage life along the blade. Validated by these approaches, the one-way FSI model and the fatigue damage model is applied to the modelling of the NREL 5 MW wind turbine blade, a representative large-scale horizontal-axis wind turbine blade. The results of the NREL wind turbine blade show that the proposed approach can provide a useful tool for assessing the structural performance and evaluating the fatigue damage of the blades during the service.

Component and system reliability in tidal turbine deployments

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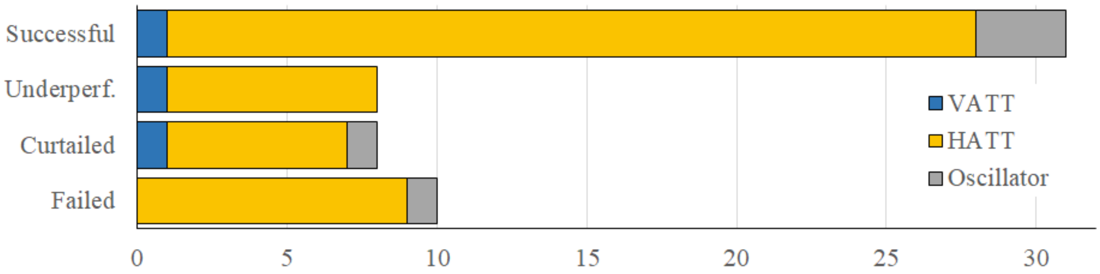
Tidal stream energy has the potential to deliver over 10% of the UK's electricity demand, and to become a significant contributor to global renewable energy generation. Though technical developments have resolved several engineering challenges and created a nascent industry with demonstration and pre-commercial installations, this potential remains largely untapped. The sector must now produce energy reliably and at a cost competitive with other sources of renewable energy. However, due to previous challenges, planned projects experience a cautious investment climate due to the perceived risk of device failure, high operational maintenance and repair costs.

To investigate likely causes, this work identified and reviewed 57 tidal stream energy deployments between 2003 and August 2020. The aim of the work was to review the commonalities, success and engineering issues, seeking to inform current and future projects in the sector. Each deployment was classified by deployment date and duration, location, device type, rated power, number of devices, grid connection and foundation type.

The performance of each deployment was then assessed against planned duration and performance using availability A_v (duration of actual generation vs duration of possible generation) as a measure. Deployments were classed as either successful (planned duration and availability achieved), underperforming (planned duration achieved but at lower availability), curtailed (withdrawn before planned duration) or failed (failure during planned duration of deployment. Results illustrate that over half of all deployments were successful, and that non-ducted horizontal axis turbine devices and fixed gravity base foundations are dominant.



Analysis of unsuccessful deployments revealed that the most common cause of failure was blade failure, followed by generator and monitoring failures. Ducted devices and devices deployed in high flow velocity locations were more likely to fail, suggesting that flow velocity is a key factor. Most blade failures were attributed to underestimation of loads at the design stage.

Deployments of devices with floating support structures were less likely to fail than those with fixed structures, but more likely to be curtailed. Off-grid and grid connected deployments showed similar failure rates, suggesting sector immaturity.

The tidal stream energy sector has to date accumulated around 1.4 million operating hours, and the analysis shows that the emergent tidal stream energy sector has a falling empirical failure rate, and a likelihood of failure similar to that experienced by the wind turbine industry at similar cumulative deployment stages. The learning rate of the sector was calculated at 10.9%, meaning that for each doubling of capacity, costs are reduced by 10.9%. As costs fall, perceived investor risk will reduce, allowing further learning by doing and cost reduction as the sector grows.

Extreme Responses of a Raft Type Wave Energy Converter

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Much attention has been paid in recent years to the determination of design loads for moored floating structures and the application of established methodologies for fixed structures have been found to be ineffective. This poster experimentally investigates extreme responses of a lazy S moored 1:20 scale model of Mocean Energy's Blue Star WEC along the 1 year return contour at the European Marine Energy Centre (EMEC). The device is a raft type WEC and the extreme responses studied include mooring loads and snatch load events. Long irregular wave time series are used in the estimation of extreme value distributions (EVD) for the design sea state and conditional random response wave (CRRW) and constrained NewWave (CNW) profiles are used in support of the predictions.

It is found that CRRWs produce larger mooring loads than CNWs except for sea states where snatch loading occurs, in which case the profiles leading to the extremes become more similar to the NewWave profile. This is due to the device behaviour deviating from the response amplitude operators (RAOs) which were used to create the CRRW profiles.

Model-Free Semi-Active Structural Control of Floating Wind Turbines

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This study addresses the load/vibration reduction problem of floating wind turbines (FWTs). Based on the tuned mass damper (TMD), a novel semi-active structural control method is designed to mitigate the floating platform's vibration. Different from existing results, the proposed control method is model-free and insensitive to system uncertainties and unmodelled dynamics. We base our design on the model-free adaptive control (MFAC) method. A data-driven surrogate model is established to approximate the unknown nonlinear system through the dynamic linearization technique. After that, a quadratic programming module is embedded in our MFAC-based semi-active structural controller for constraint handling and control allocation purposes. High-fidelity simulation results show that the proposed model-free semi-active controller can address the limitations of existing results and significantly reduce the platform's vibration.

How relative submergence changes wake recovery behind tidal stream turbines

Pablo Ouro

At every tidal site the local environmental conditions related to water depth or bathymetry distribution are different. These notably impact the flow dynamics, e.g. velocity profile distribution or bed-generated turbulence production, thus directly affecting the energy generation capabilities of tidal stream turbine arrays. Hence, there is a need to individually investigate the array layout that maximises the energy generation at any site. Relatively low submergences, i.e. when turbines occupy a large proportion of the water column, can have an immediate effect in the turbine wake dynamics, restricting its expansion and thus diminishing the recovery rate. Consequently, as this reduces the energy generation capabilities from secondary rows, it is necessary to identify and quantify the changes in the wake recovery mechanism that depend on the relative water depth.

We used the well-validated [1,2,4] large-eddy simulation (LES) code DOFAS to investigate the flow field in a small finite tidal array [4] with four relative submergence levels. LES allows to resolve the turbulence in the flow and thus quantify the transport terms involved in the Mean Kinetic Energy (MKE) equation. Figure 3 presents the profiles of turbulence-driven MKE fluxes averaged over *10D* behind the turbine. Larger water depths lead to greater vertical transport of MKE (Fig. 1a) whilst weaker horizontal transport of MKE (Fig. 1b). Our LES results show that under relatively shallow conditions, the vertical expansion of the wake is constrained when in close proximity to free-surface layer. The spread of turbulent momentum exchange across the water depth is also constrained by the free-surface presence, as observed from vertical Reynolds shear stresses. The intensity of these stresses decreases at a faster rate for shallower conditions. Conversely, levels of horizontal Reynolds shear stresses are greater for shallower flows.

Overall, our research suggesting turbine rows in arrays can be deployed more close together for ratios of water depth to turbine diameter approximately over 2.

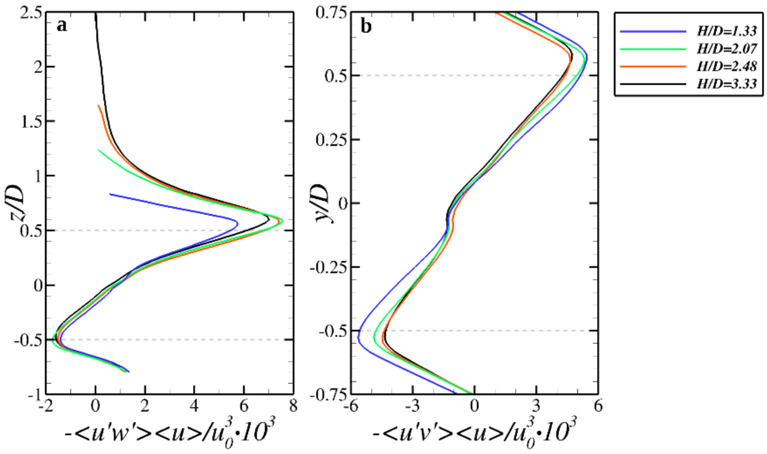

Figure 1 Vertical (a) and horizontal (b) fluxes of MKE averaged over the streamwise direction behind the middle turbine in a three in-line array.

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Progress on the design of a novel wave energy converter based on hydrodynamic lift forces (LiftWEC)

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Novel wave energy convertors (WECs) need to be designed to ensure both longevity and hydrodynamic efficiency. Hence there is a need to develop methodologies that tackle both the hydrodynamic and structural requirements of WECs. Here we demonstrate an integrated methodology for the design of LiftWEC: a wave bladed cyclorotor with two hydrofoils and a rotating shaft aligned with the wave crest. The hydrofoils follow the orbital motion of the wave particles and the phase of the rotation is different to that of the incoming wave to generate lift. By assuming two-dimensional flow and neglecting radiated wave effects, we estimate the forces on the hydrofoils due to regular and irregular waves under design conditions. By studying two rotor configurations and two typical loading cases on the hydrofoils, we demonstrate that LiftWEC is structurally resilient due to its power capping capabilities due to passive stall, i.e. the lift drops when the stall angle is exceeded. By coupling the structural and hydrodynamic models, we pave the way for novel frequency analysis studies for this type of devices.

Investigation of offshore wind turbine performance within a wind farm

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In this study, the generated power of each wind turbine, the actual wind speed and turbulence intensity in front of each wind turbine, within a 15 wind turbines wind farm (three rows with five columns) have been investigated. By investigating the generated power of each wind turbine, actual wind speed and turbulence intensity in front of the wind turbine in the wind farm, the aerodynamic wake effect within the wind farm can be discovered, which can help to optimize the wind farm operation and maintenance. A medium fidelity modelling tool – Strathfarm, have been used to simulate the wind farm, which contains the state-of-the-art wind turbine control systems, mechanical models and wake models. The DTU10MW model has been set up in Strathturb (for single turbine, the step before running Strathfarm) and validated with Bladed, which good agreement has been achieved in regards to the generator speed, hub torque, rotor thrust, blade in/out-of-plane root bending moment, tower fore-aft bending moment. In Strathfarm, the generated power, wind speed and turbulence intensity in front of each wind turbine have been investigated under three wind speeds – 7.5m/s (below the rated wind speed), 11.4m/s (rated wind speed) and 15m/s (above rated wind speed), in four directions – 0 deg, 30 deg, 60 deg and 90 deg. The input wind turbulence intensity has been set at 10%. Considering the stochasticity of the wind speed time signal, each simulation (one wind speed in one direction) has been repeated 10 times, using random seeds generated wind spectrum. Each analysis simulates 10 minutes, to represent the typical length of the load cases for fixed offshore wind turbines. Each load case with 15 minutes (the initializing for the first few minutes, which will not be considered in the data analysis) physical time will take around 1hr 30mins~2hrs to run in Windows system with around 3.86Ghz and 8Gb RAM, which is much quicker than using CFD methods.

The results of only three of the load cases – 7.5m/s at 0 deg, 11.4m/s at 90 deg and 15m/s at 30 deg, are presented in the poster. It is discovered that when the wind direction is perpendicular to the wind farm, i.e. 0 deg or 90 deg, the reduction of the power generated at the back of the wind farm is more significant compared with the wind direction is at 30 deg.

A three-dimensional regional scale model for tidal stream turbine implementation and impact assessment

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This research aims to implement a three-dimensional regional scale numerical model within a region of the Irish Sea (between 52.808˚N and 53.842˚N) that is suitable for turbine implementation and impact assessment. This research is based on a 3D wave-current-sediment fully coupled oceanographic model — the Unstructured Grid Finite Volume Community Ocean Model (FVCOM)[1], and modifications made by the authors to the current, turbulence and surface wave modules to simulate the potential impact of tidal turbines[2,3]. In the newly developed model, in order to simulate energy extraction which leads to reduced flow rate, an additional body force is added to the momentum equations at the computational cell where individual turbines are allocated. The varying turbine configuration and operation across the water column is represented by a depth-dependent coefficient for the additional body force term. Three turbulence perturbation terms are added to the MY-2.5 turbulence closure to mimic the turbine-induced turbulence generation, dissipation and interference for turbulence length-scale. The built-in function 'OBSTACLE' is used to simulate wave height drop at turbine locations.

The baseline model, i.e. without turbine implementation, is set up using Irish Sea bathymetry data extracted from a model that covers the West Coast of the UK[4]. The largest mesh size is 1600 m at the two open boundaries and the smallest mesh size is 15 m at the turbine farm location (the Sound between the Skerries and Carmel Head on mainland Anglesey, North Wales, UK) to allow turbines within the farm to be presented individually. The model is driven by tidal elevations obtained from harmonic analysis of 15 tidal constituents extracted from the High Resolution UK Continental Shelf Model (CS20-15HC3) and wave conditions provided by the ECMWF 'ERA-Interim' dataset. A time varying uniform wind field created based on data measured at the Hilbre Island weather station is used to drive the wave climate. The model is validated extensively against water level measurements at two tide gauges and wave climate collected by a WaveNet bouy. The validation results suggest that the model can accurately simulate the hydrodynamics in the configured domain.

In the case study, in total 18 turbines of 15-20 m diameter are modelled individually in the waterway between Anglesey and the Skerries. Results reveal the potential effects of the turbine farm on flow field, turbulence kinetic energy (TKE), bed shear stress and suspended sediment transport. The model is sensitive enough to detect even slight wake effects up to 4.5 km downstream of the device farm. The three-dimensional implementation is able to capture detailed vertical flow structure in the vicinity of the turbines, such as flow acceleration near the bed which may lead to enhanced bed shear stress.

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Additive Manufacturing of Micro Architecture Composite - Metal Joints for Renewable Energy Applications

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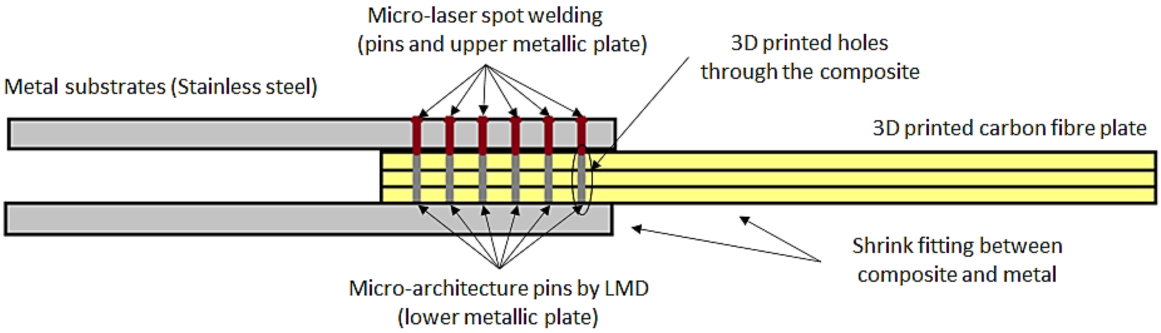
Conventional processes to join dissimilar materials, mainly metal and composite parts, result in very poor mechanical performance and durability and hinder composites' integration in different renewable energy applications. The joining of composite components with metallic structures is challenging, which has not been rigorously investigated to date. Although both fibre reinforced composites and metals are categorised as suitable structural materials, they present very different mechanical responses in terms of stiffness, strength, and coefficients of thermal expansion. Therefore, hybrid joints' design ensures dissimilar materials offer a similar load carrying capacity is a demanding optimisation exercise. Furthermore, renewable energy structures usually operate under extreme environmental conditions (pressure, seawater, temperature, humidity); thus, understanding the joints' mechanical behaviour and durability is essential.

Within this context, the emerging additive manufacturing (AM) technologies present an attractive prospect to produce bespoke joints for hybrid structures, inducing minimum damage on the substrates. Our project aims to develop a novel metal - composite joining strategy by additive manufacturing to create a micro-architecture structure. Pins are directly 3D printed in the metal part and composites are manufactured by continuous fibre deposition the geometrical discontinuities (holes, slots or groves). Afterwards, hybrid metal-composite plates will be assembled by shrink-fitting. In the final stage, a metal sheet will be joined by laser spot welding to the pins to fabricate the sandwich-joint structure of metal - composite. A numerical tool will also be developed and validated against experimental results to predict the mechanical response of critical components such as the joint between the composite blade and metallic shaft of tidal turbines.



Schematic proof of concept for 3D printed hybrid composite – metal joints.

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The potential and challenges of using drones to measure surface currents at tidal stream sites.

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Knowledge of currents at tidal stream sites is vital for resource estimation, design and maintenance operations. Standard measurements primarily use Acoustic Doppler Current Profilers (ADCPs), whether bed-mounted (point measurements) or vessel-mounted (transects). In both cases, measurements involve significant risk and cost outlay. Therefore, alternative approaches are attractive: previously X-band radar [1] and fixed video systems [2] have been used.

Video data collected by drones could provide a similar function. Large scale particle image velocimetry (LSPIV) has been previously applied to drone collected video data to measure currents in fluvial environments, e.g [3]. Drones have the advantage of being readily available and easily deployable. This means they could be used in areas where conventional survey equipment is not available, such as remote island communities, or for low-cost initial site investigation.

There are a range of challenges related to applying LSPIV to tidal stream sites relating both to image georectification and image optimization to enhance optical current signatures and minimize other signals such as waves and wind-driven ripples. These challenges are being addressed as part of the EU ERDF Selkie project.

Typically, ground control points are used to georectify images before LSPIV current extraction is performed; for many tidal sites, lack of land means fixed control points would not be possible. Therefore, image rectification will need to be conducted based solely on drone position information. The approach proposed is to fix the camera gimbal to be directly downward facing and then use GPS flight logs to calculate image shifts. Initial tests suggest that basic GPS is not sufficiently accurate to correct image shifts and so tests are underway with RTK-GPS.

It is recognized that particle seeding density has an impact on PIV results [4]; at many tidal stream sites, physical tracers are sparse and non-uniform in spatial distribution; for example, foam tracers are only present down stream of wave breaking such as current-induced whitecapping. Therefore, enhancement of more subtle surface features is important. The presence of waves can obscure these and thus a goal is to separate and remove the optical wave signature from the video data.

A final challenge is that, depending on site characteristics, surface currents measurements may not relate well to currents at turbine hub height. V-Scores, an EPSRC Supergen ORE Flexible Fund project, will address this issue through using concurrent drone, ADCP and surface drifter measurements to provide a comprehensive validation of drone-derived surface currents and comparison of surface currents and water column currents. This will be conducted at two sites: Ramsey Sound, Wales, and the Inner Sound of the Pentland Firth, Scotland.

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Supergen Offshore Renewable Energy

Plate anchors for offshore floating facilities: Soil-anchor-floating system interactions

Dr Katherine Kwa & Prof David White

This project aims to improve anchor design for floating offshore renewable energy (FORE) facilities. New anchoring solutions are currently being explored that will enable FORE facilities to operate further offshore, in deeper waters where seabeds are softer, so that they can harness stronger wind and wave resources. Developments in the mooring and anchoring system technologies are also required to unlock large scale commercialisation for FORE facilities and enable them to operate more efficiently, as arrays. FORE arrays will occupy areas up to several square kilometres that will span across multiple seabed types with varying geomaterial properties. However, there is a disconnect between characterising the geotechnical conditions of the seabed and integrating these into the design process of the anchoring and mooring systems, and there is a risk that this will result in overly conservative and more expensive anchor and mooring designs.

The embedded plate anchor and mooring system is an efficient and versatile foundation solution, and is used as the example anchor type to illustrate more general features of seabed behaviour. The capacity of this anchoring system is enhanced by the strength and weight of the surrounding soil which resists uplift of the plate. It is essential to have a reliable estimation of the uplift capacity that the plate anchor can provide for the variety of loads that are transmitted via the mooring lines to the anchoring system. However, in soft soils, this capacity can evolve with time due to the sustained loads and variable components of the cyclic uplift loads, which vary due to sea state, season, and the operational requirements of the connected floating offshore renewable energy (FORE) system. There is also an emerging concept of the ‘whole life’ response of soft soils which suggests that over the operational lifetime of FORE infrastructure, the capacity of the plate anchor rises due to consolidation effects associated with sustained and cyclic loading. During the application of higher frequency loads such as snatch loads, viscous and inertial or ‘added mass’ effects from the seabed soil surrounding anchoring systems can also result in significant increases in dynamic anchor capacities that are overlooked in anchoring design.

This study will present and discuss the anchor capacity enhancement effects from consolidation on the changing static anchor capacity and the positive contributions from seabed viscous and the added mass effects during rapid loading conditions on the dynamic anchor capacity. It shows how these effects, currently overlooked in conventional anchor design, can be integrated into a coupled anchor-mooring model which provides a new basis for assessing the through-life changes in geotechnical anchor capacity and enable a better understanding of the fully coupled soil-anchoring-mooring behaviour of FORE infrastructure over its operational lifetime. Allowing for these whole-life changes in seabed strength and the viscous and added mass seabed-anchor interactions, also has beneficial design outcomes. It offers opportunities for more cost-effective and efficient anchoring systems resulting in reductions in anchoring size, reduced risk of fatigue, greater insight for late life management and informed decommissioning processes for FORE infrastructure.

Further Reading:

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- Laham, N., Kwa, K., White, D., & Gourvenec, S. (2020). Episodic direct simple shear tests to measure changing strength for whole-life geotechnical design. Geotechnique Letters.
- Kwa, K., & White, D. (Submitted). Plate anchors for floating offshore facilities: soil-anchor-floating system interactions. 20th ICSMGE *delayed to 2022*. Sydney, Australia.
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Impact of spatially varying onset flow conditions on loading of a tidal turbine

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At this point in time the tidal energy sector is advancing with the development of horizontal axis turbines for deployment into arrays. The locations of turbines within these arrays will primarily be based upon the maximum power output achievable, which is established through knowledge of site conditions and the setup of large scale hydrodynamic models. These models rely on ambient conditions and do not take into consideration the unsteady variation of onset flow on each individual turbine. With variations in periodic and aperiodic conditions from turbine wakes and turbulence contributing to unsteady loads on turbine blades an analysis of the variation of onset flow conditions within one site is of interest. With the main motivation to be to establish the variation in loads for multiple cases which are considered to have the same quasi-steady onset flow condition.

The influence of unsteady conditions on the fatigue loading of tidal turbines using an efficient blade element theory method, which is shown in predict loads within 6% of experimental measurements. Datasets from the ReDAPT project have been used to compare the variation in loads from two measurement locations over a simultaneous period of time. With onset conditions modelled using two different turbulence modelling methods to create stochastic velocity fluctuations around the power weighted reference velocity given at the site. Turbulence characteristics have been determined for each location and turbine position within the site and show a 30% difference between site locations for the lengthscale over a wide range of fluctuation intensities. Preliminary results have shown a 13% difference in damage equivalent loads on a turbine blade between the two different locations with no shear considered. With an overall increase in loads at each position and location when the average shear profile from the site measurements is included. With plans for the dependency of unsteady shear vs turbulence on the damage equivalent loads the next stage of development.

Topside bridge effect on the dynamic response of multi-purpose offshore platform under extreme conditions

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The multi-purpose offshore platforms are a promising way to meet the increasing demand for green energy and at the same time decrease the environmental pressure on oceans exerted from marine infrastructures. The integration of various functional units into one, the sharing use of infrastructure, and the combination of various offshore energy generation resources make the multi-purpose offshore platforms be both economic and efficient solution for the offshore renewable energy industry. An environmentally friendly multi-purpose offshore platform is developed by 'the Blue Growth Farm' (BGF) project (Programme H2020-EU.3.2.5), which includes a square-shaped concrete platform, a wind turbine, a set of wave energy converters, and an aquaculture system. This multi-purpose offshore platform is well suited for open sea farm installation in terms of the Blue Growth Industry.

The numerical analysis of the BGF platform is an important part of the whole project. An aero-hydro-elastic numerical model is developed to investigate the aerodynamic and hydrodynamic performance of the BGF platform, including the aerodynamic response of the wind turbine, the hydrodynamic response of the platform and mooring system etc. As a conventional choice for dynamic analysis, the topside building is not modelled, and its weight is compensated into the platform. This treatment gives a simplification to the numerical analysis, but on the other hand, the effect of the topside building on the platform motion is neglected, which may cause underestimation of the platform response especially under extreme conditions such as high wind speeds. This poster presents an investigation of the topside bridge effect on the response of the BGF platform under high wind speed conditions. The comparison between the platform motion response with and without the topside bridge is provided. Besides, an analytical calculation is performed by using the 'Morrison type' equation to estimate the wind forces on the structures above the water surface. Both the wind turbine blade areas and the part above the water surface of the BGF platform are considered under the loading conditions of wind with constant speed and different directions. Thus, the effect of the topside bridge on the response of the BGF platform is estimated both by analytical and numerical methods.

An off-grid floating oscillating-water-column for powering oceanographic instruments

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A conventional solution for powering oceanographic monitoring systems (e.g. Acoustic Doppler Current Profilers (ADCPs), wave and current measurement buoys) is a solar photovoltaic (PV) module with battery storage. Nevertheless, due to the photovoltaic resource's diurnal nature, a battery bank with a large storage capacity must be used to enable the system to run autonomously for a sufficient amount of time. Hence, a small wave energy converter or a hybrid wave-solar converter could offer a more reliable solution [1,2,3]. The project aims to evaluate the potential of a floating oscillating-water-column (OWC) wave energy converter in powering oceanographic monitoring systems. The spar-buoy OWC concept [4] typically considered for large-scale energy production can be redesigned to meet the power requirements of oceanographic equipment. This modification results in a much smaller device working outside resonance conditions under typical sea states, and therefore with a smaller energy conversion efficiency [1,2]. Experiments were undertaken for a 1:10th scale model in a wave channel for regular and irregular waves [3]. A calibrated orifice plate was used to model an impulse turbine's flow characteristic, which will be utilised in the full-scale system. Non-linear effects were apparent for regular-wave results around the natural frequency, linked to the viscous damping. The irregular wave tests were conducted to validate the output from a non-linear stochastic formulation [5] which predicts irregular wave quantities based on regular-wave data. The generally good agreement between the experimental irregular-wave results and those obtained from the stochastic model using experimental regular-wave data supported the generation of a power matrix. It is concluded that the power available to the turbine is sufficient for oceanographic instruments' power supply, considering a wave climate off the Outer Hebrides.

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Hydrodynamic performance of submerged hydrofoils subject to heave and pitch motions

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Flow passing a foil object will produce lift and drag forces, as well as vortex street BvK. With right parameters, a periodic motion of an object in fluids will generate thrust rather than drag. To reduce the study's complexity, only kinematics parameters were modified and not the geometric ones. The hydrofoil interactions with waves have been investigated using an inhouse CFD code. First, the lift and drag coefficients were validated against the literature. Thereafter, different oscillation parameters, according to the sea state, were studied to optimize the performance of the thrust. From these results it appeared that it is possible to generate thrust at sea state. The numerical model successfully represented the flapping foil interactions with water, the BvK reversed vortices and the leasing-edges vortices. It also allowed observing the global trend of the impact of the flapping motion on thrust generation.

Keywords: Flapping hydrofoil, Numerical modelling, Thrust generation, Reversed von Kármán street

Modeling validation of hinged-raft wave energy converter using WEC-SIM

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This study evaluates the feasibility of using the free open-source modeling package Wave Energy ConverterSIMulator (WEC-Sim) code to model a hinged-raft wave energy converter (WEC). WEC-Sim has been widely used to model the performance of oscillating body WECs, e.g., point absorbers, oscillating surge WEC and OWC. Hinged-raft WECs are a different type of WEC, needing to consider the body-to-body interaction between the rafts, the constraint under the hinge, the phase difference between the rafts. A generic hinged-raft WEC is selected and studied here. A comparison of simulation using WEC-Sim and published analytical results is conducted to evaluate the feasibility of using WEC-Sim for hinged-raft WEC modeling. The results show that WEC-Sim can model the performance of hinged-raft effectively, with the scripts under function 'Read_AQWA' modified.

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Climate change impact on structural performance of offshore wind turbines

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Offshore wind turbines (OWTs) must be sufficiently robust and resilient to withstand windstorms over an operational life of 20-25 years in an aggressive marine environment. Current performance-based assessment methods for OWTs often neglect structural failure and focus on equipment failure only, which can be assessed using existing empirical databases. This study uses a simulation-based approach to assess various performance metrics associated with offshore wind infrastructure exposed to operational wind and wave conditions. Surrogate modelling is used to predict structural failure due to fatigue in a computationally efficient manner. The proposed surrogate model is based on Gaussian process regression and allows one to run structural simulations at a small training sample of wind and wave conditions and emulates the response at combinations where the OWT was not explicitly assessed. This result in an integrated probabilistic performance-based assessment framework for OWTs that considers both structural and non-structural (equipment) components. In particular, the proposed framework is used to evaluate the potential impact of climate-change scenarios on various OWT performance metrics, namely, fatigue damage, fatigue reliability and, ultimately, financial losses (cost of direct damage) for a case study OWT. This is compared to the change in revenue resulting from power production to understand which is more sensitive to climate change. Both fatigue damage and structural safety are found to be sensitive to changes in the site environmental conditions. However, as financial losses additionally depend on non-structural components - which are typically characterised by much higher failure rates - they are found to be less sensitive to the considered climate-change scenarios.

Capacity of Driven Piles in Chalk

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Chalk is encountered under large areas of north-west Europe as a low-density, porous, weak carbonate rock. While offshore wind turbines often rely on large-scale tubular steel foundations driven in chalk, there is currently no established method for design in these materials. For predominantly axially loaded piles, current European practice assumes ultimate shaft resistances for axially loaded piles that appear low in comparison with the chalk's unconfined compression strength and CPT cone resistance ranges. There is also no established method for design of large-scale monopiles in chalk, which are predominantly subjected to lateral loading. Little guidance is available on pile driveability, time effects or on how piles driven in chalk can sustain axial or lateral cyclic loading. Taken together, these uncertainties in design can impact very significantly on project economics.

The aim of the ALPACA (Axial-Lateral Pile Analysis for Chalk Applying multi-scale field and laboratory testing) and ALPACA+ projects, funded by EPSRC and Industry, is to develop new design guidance through comprehensive field testing at a well characterised low-to-medium density test site in Kent, UK (Jardine, et al. 2019). A total of 40 driven piles at a range of scales have been installed, 20 of which employ highly resolution fibre-optic strain gauges. The piles were monitored continuously during driving and novel methods were used to interpret the results (Buckley, et al. 2020). The main ALPACA test programme, which consisted of axial and lateral static and cyclic pile tests, was completed in 2019. The ALPACA+ programme, which aims to investigate the influence of additional phenomena including pile geometry will be completed in 2021. The field experiments are supported by in situ tests and advanced laboratory testing on intact and remoulded chalk.

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