World-class research and technology transfer in marine energy

5th PRIMaRE Conference

5-6th July 2018

University of Bristol

Conference Programme

www.primare.org

Introduction

Dear PRIMaRE Delegates,

A warm welcome to the 5th PRIMaRE Conference, hosted by the University of Bristol.

Over recent years, PRIMaRE has gone from strength to strength, developing a range of new partnerships through the Annual Conference and many other networking and knowledge transfer events. In the last year, we have welcomed Cardiff University as a full Partner, and Loughborough University as a new Associate Partner, whilst forging strong links with marine renewable energy groups across the UK and overseas. This has been facilitated by a major EPSRC Networking Grant awarded in 2017, which will provide additional funding until 2020 for workshops, summer schools, research exchanges and other knowledge sharing activities.

The Network Grant has already been used to develop a new PRIMaRE website, with improved information about the consortium's broad range of research expertise and opportunities to work with us. It will also soon include a dedicated section on skills and training so, if you haven't already done so, please visit the website and register for the newsletter to be kept updated on future developments. Special thanks are due to Carlos Perez-Collazo, a PRIMaRE Research Fellow, who has worked tirelessly on both the website and the organisation of many other PRIMaRE activities over the past year.

The variety of presentations from both academia and industry at this year's conference is testimony to the success of the PRIMaRE network in promoting collaboration and the huge potential for ongoing R&D in marine renewables. The sector must address major challenges around cost and risk reduction if marine energy is to play a significant role in our future low carbon energy mix. Although offshore wind has seen rapid growth over recent years, the wave and tidal sectors have experienced significant setbacks, with several leading companies falling into financial difficulties and the UK government deciding not to back the proposed Swansea Bay tidal lagoon. The ongoing work of R&D facilities such as Wave Hub and the European Marine Energy Centre (EMEC), alongside flagship commercial projects like MeyGen, show that the industry still has a strong platform for future success, but only with the backing of carefully targeted government support schemes. This will be the core focus of our Thursday evening panel discussion, which will feature views from a range of leading figures in the marine energy sector.

It seems fitting to end this introduction with a word of congratulations to Professor Deborah Greaves, who was recently awarded an OBE for her enormous contribution to research in offshore renewable energy. Deborah has been one of the key driving forces behind PRIMaRE and is currently leading the new Offshore Renewable Energy SuperGen Research Hub, which will act as an essential catalyst for building further expertise linked to offshore wind, wave and tidal energy technologies.

I hope that this year's conference promotes a range of new collaborations, helping to ensure that the UK remains a world leader in marine renewables and allowing the sector to achieve its full commercial potential.

Best wishes for an enjoyable time in Bristol and a large thank you to everyone who has made this year's event possible, including the participants, sponsors and all those who have helped with the organisation.

Paul Harper

PRIMaRE Chair 2018
University of Bristol

Conference Sponsors

In addition to the PRIMaRE Network, the conference is being generously supported by the University of Bristol's Cabot Institute for the Environment and the School of Civil, Aerospace and Mechanical Engineering (CAME).

PRIMaRE Overview

The Partnership for Research in Marine Renewable Energy (PRIMaRE) is a consortium of marine renewable energy experts across higher education, research and industry which have joined together to establish a network of excellence centred in the south of the UK. The work of PRIMaRE aims to address the research and development challenges facing the Marine Renewable Energy (MRE) sector, including wave, tidal stream, tidal range and offshore wind. The main Partner organisations are the Universities of Plymouth, Exeter, Southampton, Bristol, Bath and Cardiff, along with the Marine Biological Association of the UK and Plymouth Marine Laboratory. We also work closely with a number of Associate Partners, including Wave Hub, Regen and the Universities of Cranfield, Loughborough and Uppsala.

Partners

Associate Partners

Steering Committee

Deborah Greaves (University of Plymouth)
Carlos Perez-Collazo (University of Plymouth)
Lars Johanning (University of Exeter)
Philipp Thies (University of Exeter)
Jun Zang (University of Bath)
Philippe Blondel (University of Bath)
Paul Harper (University of Bristol)
Andrea Diambra (University of Bristol)
AbuBakr Bahaj (University of Southampton)
Luke Blunden (University of Southampton)
Tim O'Doherty (Cardiff University)

Mel Austen (Plymouth Marine Laboratory)
Tara Hooper (Plymouth Marine Laboratory)
Jon Parr (Marine Biological Association)
Johnny Gowdy (Regen)
Kerry Hayes (Regen)
Claire Gibson (Wave Hub)
Stuart Herbert (Wave Hub)

General Information

Location and Directions

The conference will take place in the Bill Brown Suite of Queen’s Building, part of the University’s Faculty of Engineering. The full address is as follows:

Bill Brown Suite, Queen’s Building New Wing, Woodland Road, University of Bristol, BS8 1TR

Please note that the entrance to the Bill Brown Suite is separate to the main entrance of Queen’s Building and a map for directions can be found at the following link:

Bill Brown Suite Location Map (look for the entrance shown in the picture below)

Those travelling by train to Temple Meads Station can either:

- Take the number 8 or 9 buses operated by ‘First Bus’ from directly outside the train station to the top of Park Street opposite Wills Memorial Building (c. 20 minute bus journey, plus a 2 minute walk to Queen’s Building).
- Travel by taxi from outside Temple Meads Train Station (c. 20 minute journey, c.£10)
- Walk (c. 35 minutes with a reasonably steep hill)

Further guidance for those travelling by plane, car, or coach can be found at:

http://www.bristol.ac.uk/maps/directions/

Accommodation

Please note that this is a list of accommodation local to the Queen's Building (The Radisson Blu and Marriott hotels are both mid-way between Queen's Building and the conference dinner venue) and the University of Bristol does not endorse all of these hotels. Costs are indicative only, and will change dependent upon availability and the time of booking:

- **The Radisson Blu**, Broad Quay, Bristol, BS1 4BY (from £72 pppn)
- **The Marriott**, College Green, Bristol, BS1 5TA (from £108 pppn)
- **The Clifton Hotel**, St Paul's Road, Clifton, Bristol, BS8 1LX (from £59 pppn)
- **The Rodney Hotel**, 4 Rodney Place, Clifton, Bristol, BS8 4HY (from £57 pppn)
- **Berkeley Suites: The Crescent**, 6 Berkeley Crescent, Bristol, BS8 1HA (serviced suites from £131 pppn)
- **Berkeley Square Hotel**, 15 Berkeley Square, Clifton, Bristol, BS8 1HB (from £73 pppn)
- **Washington Hotel**, St Paul's Road, Clifton, Bristol, BS8 1LX (from £42 pppn)
- **Best Western Victoria Square Hotel**, Victoria Square, Clifton, Bristol, BS8 4EW (from £50 pppn)
- **Clifton Towers** (B&B), 10 Clifton Hill, Clifton, Bristol, BS8 1BN (from £45 pppn)
- **9 Prince's Buildings** (B&B), 9 Prince's Buildings, Clifton, Bristol, BS8 4LB (from £60 pppn)
- **Emmaus House** (B&B), Clifton Hill, Clifton, Bristol, BS8 1BN (from £45 pppn)
- **The Belgrave** (B&B), 25 Upper Belgrave Rd, Clifton, Bristol, BS8 2XL (from £45 pppn)
- **North Green Lodge** (B&B), 6 Dowry Square, Hotwells, Bristol, BS8 4SH (from £50 pppn)

Visiting Bristol

Bristol was named European Green Capital in 2015, a Rockefeller Resilient City in 2016, UNESCO City of Film in 2017 and overtook London as the UK's leading 'smart city' according to the second UK Smart Cities Index in 2017.

We hope that you have some time to experience Bristol's sights during your stay and recommend the Visit Bristol website for all tourist advice.

Nearby attractions include:

- SS Great Britain
- Clifton Suspension Bridge for views of the city
- Cabot Tower and Brandon Hill for views of the city
- Royal West Academy of England art gallery
- We the curious science centre
- Banksy walking tour of graffiti art

Conference Dinner

The Conference Dinner on the evening of Thursday 5th July will be at Riverstation (The Grove, Bristol, BS1 4RB), a popular restaurant on Bristol's harbourside, which is about a 15 minute walk from Queen's Building. For those who have registered to attend, a 3 course menu will be provided, with a choice of fish, meat and vegetarian options.

Conference Schedule

Thursday 5th July 2018 (Morning)

9:00-10:00	**Coffee & Registration**
10:00-10:10	**Welcome & PRIMaRE Overview** P. Harper – University of Bristol
10:10-11:10	**Session 1: Wave Energy – Numerical Modelling**
10:10	Performance Optimization of a Coaxial-Cylinder Wave Energy Converter B. Zhou – Harbin Engineering University *(Abstract included in programme but did not present)*
10:20	Wave Slamming on a Flap-Type Wave Energy Converter E. Renzi – Loughborough University
10:30	Nonlinear Model of Curved-Shape Oscillating Wave Surge Converters S. Michele – Loughborough University
10:40	Optimisation of WEC Type Floating Breakwaters J. Birchall – University of Bath
10:50	An Optimisation Approach of a Wavesub Array E. Faraggiana – Swansea University
11:00	A Wave Energy Converter for Small Communities: Modelling of a Compliant Power Take-Off A. Kyte – University of Plymouth
11:10-11:50	**Refreshments & Poster Display**
11:50-12:10	**Invited Talk: Research & Development in Marine Renewables at The University of Western Australia** Ian Milne - University of Western Australia
12:10-13:00	**Session 2: Floating Wind Energy**
12:10	Beyond OC5 – Further Advances In Floating Wind Turbine Modelling With Bladed B. Child – DNV GL
12:20	Simulation Methodology of Floating Offshore Wind Turbine Platforms with Porous Outer Layers with OpenFOAM A. Feichtner – University of Exeter
12:30	A CFD Analysis of the Aerodynamics of a Floating Wind Turbine R. Smith – University of Exeter
12:40	Appraisal of an Intelligent Mooring System for Floating Offshore Wind M. Harrold – University of Exeter
12:50	Multi-Objective Optimization of Mooring Systems for Offshore Renewable Energy Devices A. Pillai – University of Exeter
13:00-14:00	**Lunch**

Conference Schedule

Thursday 5th July 2018 (Afternoon)

14:00-15:10	**Session 3: Tidal Energy – Numerical Modelling**
14:00	Theoretical Power and Energy Estimation of the Tidal Range Resources in the Northern Gulf of California, Mexico C.J. Mejia-Olivares – University of Southampton
14:10	Optimisation of Tidal Turbine Blades with Winglets R. Alvero Trejo – University of Southampton
14:20	Tidal Stream Turbine Configurations for Low Speed Flow T. Hernandez-Madrigal – Cardiff University
14:30	Design Process for a Scale Horizontal Axis Tidal Turbine Blade R. Ellis – Cardiff University
14:40	Wave-Current Numerical Modelling using Stokes 2nd Order and Linear Wave Theory C. Lloyd – Cardiff University
14:50	Distortion of Tidal Flow Turbulence Incident on a Horizontal Axis Tidal Turbine M. Graham – Imperial College London *(I. Milne presented)*
15:00	Modelling the Tidal Stream Energy Resource in Indonesia A. Goward Brown – Bangor University
15:10-15:40	**Refreshments & Poster Display**
15:40-16:00	**Invited Talk: Experiences Developing Tidal Stream Energy in Indonesia** M. Spencer - SBS International Ltd *(S. Spall presented)*
16:00-16:40	**Session 4: Device Installation, Operations & Maintenance**
16:00	Offshore Energy Planning Provisions and Transnational Maritime Spatial Planning in the North Sea Region: Findings from the NORTHSEE Project K. Wright - Marine Scotland Science
16:10	Cost Reduction in Tidal Stream Energy Through Operational Modelling S. Jermy – James Fisher Marine Services Ltd
16:20	Decommissioning of the Ex-TGL Tidal Turbine Tripod T. Warren - Blackfish Engineering Design Ltd
16:30	FaBTest – A Nursery Site for Marine Renewable Energy Devices G. Crossley – University of Exeter
16:40-17:00	**Refreshments & Poster Display**
17:00-18:30	**Panel Debate: Future Cost Reductions and Industry Growth in the Marine Renewable Energy Sector** Chair: Kerry Hayes (Regen) Panel: Sue Barr (Marine Energy Council), Stuart Herbert (Wave Hub), Deborah Greaves (ORE SuperGen), Mark Leybourne (ITPEnergised), Rob Bray (Atlantis), Peter Kydd (Independent Consultant)
19:15-20:30	**Conference Dinner - Riverstation**

Conference Schedule

Friday 6th July 2018 (Morning)

9:00-10:00	**Coffee & Networking**
10:00-11:10	**Session 5: Wave Energy - Device Development & Testing**
10:00	Tests of a Fylfot-Shaped Wave-Energy Generator M. McCulloch – University of Plymouth
10:10	An Accurate and Cost Efficient Physical Scale Model of a Direct Driven Point-Absorber with Constant Damping Power Take-Of S. Thomas – Uppsala University
10:20	Laboratory Tests of a Novel Wind-Wave Energy Converter C. Perez-Collazo – University of Plymouth
10:30	Use of HF Radar for Replicating Complex Wave Conditions for Testing of Wave Energy Converters D. Wang – University of Plymouth
10:40	Applications of Image Recognition Techniques in Hydrodynamic Experimental Testing R. Pemberton – University of Plymouth
10:50	Development of Uppsala’s Wave Energy Converter: Optimisation of a Linear Generator T. Potapenko – Uppsala University
11:00	Development of Uppsala’s Wave Energy Converter: Powering a Desalination Plant to Generate Freshwater J. Leijon – Uppsala University
11:10-11:40	**Refreshments & Poster Display**
11:40-12:00	**Invited Talk: Materials Research & Development in Marine Renewables at IFREMER** P. Davies - IFREMER
12:00-12:50	**Session 6: Structures, Materials & Geotechnics**
12:00	Application of Composites to Thick Marine Structures O. Parks – Airborne Composites & University of Bristol
12:10	Advanced Design and Manufacture Concept of a Bend-Twist Coupled Wind Turbine Blade T. Macquart – University of Bristol
12:20	Study on Mooring Compounds for Offshore Floating Applications F. Xanthaki – University of Plymouth
12:30	Macro Modelling of Anchoring Systems for Floating Offshore Structures A. De Silva – University of Bristol
12:40	Application of Spectral Analysis to Predicting the Vertical Conformity and Lateral Resistance of Subsea Cables and Pipes over Rocky Seabeds T. Griffiths - University of Western Australia
12:50-13:00	**Poster Prizes & Conference Photo**
13:00-14:00	**Lunch**

Conference Schedule

Friday 6th July 2018 (Afternoon)

14:00-14:50	**Session 7: Tidal Energy - Device Development & Testing**
14:00	Development of a Floating Platform for Shallow Water Tidal Stream Energy Resources J. Hussey - Instream Energy Systems *(G. Bawn presented)*
14:10	Validation of a Nonlinear, Coupled Numerical Model for Assessment of Floating Tidal Systems S. Brown – University of Plymouth
14:20	Tidal Rotor Performance Assessment in Three Test Facilities F. Trarieux – Cranfield University
14:30	Could Large Tidal Turbine Arrays Affect Nearby Sandbanks? L. Blunden – University of Southampton
14:40	The Development and Testing of a Lab-Scale Tidal Stream Turbine for the Study of Dynamic Device Loading M. Allmark – Cardiff University
14:50-15:00	**Closing Remarks & PRIMaRE Chair Handover (Bristol to Cardiff)**
15:00	**Conference Close**

Poster Presentations

Posters will be displayed in the Bill Brown Suite throughout the conference. The best three posters produced by PhD students, as judged by a mystery panel, will be awarded a copy of the new book on Wave and Tidal Energy, edited by Deborah Greaves and Gregorio Iglesias, and generously donated by the publishers, John Wiley & Sons Ltd. Entries include:

- Grid Connection of a Marine Current Energy Converter (J. Forslund, Uppsala University)
- Are the strongest magnets always the best? (J. Leijon, Uppsala University)
- 3D Modelling of Swansea Bay Tidal Lagoon using DELFT3D (N. Coz, Cardiff University)
- Parameterisation of an Offshore Multi-MW Wind Turbine Blade for Optimisation (S. Scott, University of Bristol)
- DyLoTTA Project: Wave-Current Modelling and Turbine Development using CFD (C. Lloyd & R. Ellis, Cardiff University)
- Productive Benthic Algal Ecosystem Drives Silicon Dynamics in the Severn Estuary (H. Welsby, University of Bristol)
- Hydrodynamics of flexible piezoelectric wave energy converters (F. Buriani, Loughborough University)
- The application of composite materials within a marine environment (O. Parks, Airborne Composites & University of Bristol)
- Integrated strain and fracture sensing in carbon nanotube reinforced composites (M. Al-Bahrani, University of Plymouth)
- The Effect of Solidity on a Tidal Turbine in Low Speed Flow (T. Hernandez-Madrigal – Cardiff University)
- Optimization Of Floating Breakwater-Based Wave Energy Converters (J. Birchall, University of Bath)
- Parametric excitation of mooring lines (Y. Zhang, University of Bristol)
- Interface strength of polypropylene pipeline coatings (L. de Leeuw, University of Bristol)
- Mix design of FA-GGBFS and HMNS based geopolymer concrete as binder suitable for marine applications under ambient conditions (A. Bouaissi, University of Plymouth)
- Modelling of a Wave Energy Converter (T. Potapenko, Uppsala University)
- Comparisons for Different Operational Schemes of Swansea Bay Tidal Lagoon using TELEMAC2D (B. Guo, Cardiff University)
- Stress Analysis of Bolted FRP Flange Connections Under Internal Pressure (M. Aljuboury, University of Plymouth)
- An Optimisation Approach of a Wavesub Array (E. Faraggiana, Swansea University)
- Experimental On-Shore Studies of a Linear Generator for Wave Power (A. Frost, Uppsala University)
- Theoretical power and energy estimation of tidal range resources in the northern Gulf of California, Mexico (C.J. Mejia-Olivares – University of Southampton)

Invited Talks

Research & Development in Marine Renewables at the University of Western Australia

Ian Milne, University of Western Australia

Ian Milne completed his PhD at The University of Auckland, New Zealand, in 2014. His thesis characterised the unsteady loading on tidal turbine blades due to turbulence and was undertaken in collaboration with UK universities and tidal energy developers. Following a period working in industry, he joined the University of Western Australia (UWA) in 2016 as a Research Fellow within a rapidly growing team specialising in offshore hydrodynamics and marine engineering.

Ian will provide an overview of R&D activities and industry engagement within marine renewables at The University of Western Australia's Oceans Institute. The establishment of the Wave Energy Research Centre in Western Australia, as well as outcomes of novel studies on turbulence as part of the Islay and MeyGen tidal energy projects in the UK will be highlighted.

Experiences Developing Tidal Energy in Indonesia and CEARS

Mike Spencer, SBS International Ltd

Mike Spencer is Group Chairman & CEO of the SBS International Ltd group. He is a former British Royal Navy marine engineer and military diver with special operations experience and MBA schooling. He was a commercial deep sea saturation diver, dive superintendent and operations manager for a major international underwater engineering firm for 10 years before forming SBS in Aberdeen in 1989. SBS is a marine, subsea and renewable energy project developer, with global Oil & Gas industry experience, which has specialist low carbon engineers and partners involved in more than 50% of UK Marine Energy projects over the last 17 years.

Mike will present some of his experiences in Indonesia during the last 5 years with the Nautilus tidal-stream energy project. Nautilus is presently at post-feasibility, pre-power purchase agreement development stage. It is designed to deliver 150MW from 100 x 1.5MW tidal turbine generators from UK OEM, Atlantis Resources Ltd. The project started in early 2013 and the first two years focused on evaluating tidal resources around the Indonesian archipelago and optimising the concept definition. Mike will also discuss collaboration between industry and academia and how the CEARS (Indonesian Centre of Excellence for Academic and Research Studies in Marine Renewable Energy) concept has evolved. CEARS will involve a partnership between UK and Indonesian universities and represents an opportunity for academia to have direct industry interaction with a live, commercial-scale, tidal-stream project.

Materials Research & Development in Marine Renewables at IFREMER

Peter Davies, Marine Structures Laboratory, IFREMER

Peter Davies (FIMMM) works in the Marine Structures group at the French Ocean Research Institute (IFREMER) in Brest. He joined the Institute in 1991, after a PhD in France and a post-doc at the EPFL in Switzerland. He works with industrial and academic partners on the durability of polymers and composites for marine applications.

Peter will present an overview of Materials Research and Development in Marine Renewable Energy (MRE) at IFREMER, which has been working on MRE for many years. Studies extend from analysis of ocean energy resources through materials and structural testing to hydrodynamics, operations at sea and environmental impact assessment. Peter's group is focused on the durability of materials for marine applications and works on three main areas:

- Fibre reinforced composites, for structural applications such as tidal turbine blades;
- Long term behaviour of synthetic fibre ropes for moorings, and;
- Elastomer durability in seawater.

After a short general introduction to IFREMER's activities in these areas, the presentation will describe examples of the material durability studies which have been performed, and discuss some of the requirements for improved reliability of MRE components.

Panel Discussion

Future Cost Reductions and Industry Growth in the Marine Renewable Energy Sector

This year's conference will include a panel discussion addressing the challenges facing the UK marine energy sector and the solutions available to overcome the barriers to development. It will include an overview of the predictions of cost reduction that the large-scale deployment of marine energy technologies could provide and a briefing on the proposed Innovation Power Purchase Agreement (IPPA), an alternative revenue support model for emerging generation technologies such as marine energy and floating offshore wind. The discussion will also explore views on the benefits that the marine energy sector could provide to the UK across numerous critical areas such as jobs and exports, in addition to the supply of predictable, low-carbon energy.

Chair: ***Kerry Hayes, Marine Energy Sector Lead, Regen***

Kerry is the marine energy sector lead at Regen, an independent not-for-profit organisation that uses its expertise to work with industry, communities and the public sector to promote renewable energy and energy efficiency. She has a broad range of experience in marine and offshore energy, focusing on data analysis and supply chain development, and takes a lead in planning, consenting and energy policy. Kerry has also worked with two marine energy project development companies, leading on consenting and overall project development. Kerry is an associate lecturer at the Marine Learning Alliance and the universities of Plymouth and Exeter.

Panel Members:

Sue Barr, Marine Energy Expert, RUK, Scottish Renewables, Marine Energy Wales and Chair of UK Marine Energy Council

Sue has 18 years' experience in the offshore wind, wave and tidal industries, including 11 years at OpenHydro, a tidal technology developer, in senior management, project development, policy and developing marine energy markets. She supported the UK Government delivering the first offshore wind arrays including revision of primary legislation, administering regulatory controls and advised UK Ministers on the first marine energy projects. On the board of all three industry associations and chair of the UK Marine Policy Forum & Council, she plays a key role in driving renewable industry policy in the marine sector, in the UK and internationally.

Deborah Greaves, Professor of Ocean Engineering, University of Plymouth

Deborah Greaves is Head of the School of Engineering, Professor of Ocean Engineering and Director of the COAST (Coastal, Ocean and Sediment Transport) Laboratory at the University of Plymouth, with previous appointments at UCL and the University of Bath. Her research interests include physical and numerical modelling of wave-structure interaction. She has led many national and international research projects concerning offshore renewable energy (ORE) in collaboration with industrial and academic partners and in 2017 was appointed by EPSRC as the new ORE SuperGen Leader. She has published over 150 peer-reviewed papers, secured £9.3 million research income and was awarded an OBE for her contributions to research into offshore renewable energy.

Stuart Herbert, Business Development Director, Wave Hub Ltd

Wave Hub Ltd, based in Cornwall (UK), manages offshore test sites to advance the development of offshore renewable energy technologies. Stuart joined Wave Hub in 2013 to lead negotiations with companies planning to use the test site and identify new business opportunities. Prior to joining Wave Hub, Stuart worked as commercial and operational manager for the SGS Renewable energy services division and as business development manager for the National Renewable Energy Centre (Narec) in the North East of England, focusing on marine energy device and wind turbine testing.

Peter Kydd, Consultant, WSP

Peter Kydd has 40 years' experience as a consulting engineer working in the UK and overseas primarily on hydropower, environmental, marine and river engineering projects. For much of this time, he was a member of Parsons Brinckerhoff's senior leadership team with responsibility for the environment and strategic consulting business units. He led the technical studies for the UK Government's Severn Tidal Power Feasibility Study between 2008 and 2010 and since then has advised them on tidal power projects including Swansea Bay and other tidal lagoon projects. He chaired the South West Marine Energy Park from 2012 to 2017 and continues to act as a consultant to WSP on tidal power and river engineering projects.

Mark Leybourne, Associate Director, ITPEnergised

Dr Mark Leybourne is an Associate Director in ITPEnergised's offshore renewable energy group, based in Bristol, UK. Mark works across a range of offshore wind, wave and tidal energy projects, providing technical, engineering, policy and strategic advice to both public and private clients. After joining the consultancy 10 years ago, he is now responsible for the company's international offshore renewable energy work, with a strong focus on Asian markets. Mark is currently leading a tidal turbine design project for China Three Gorges and has recently worked on European tidal energy projects for Morlais, PTEC and Minesto. He is also currently leading the third-party engineering advisory work for Wave Energy Scotland's novel wave energy converter programme.

Jeremy Thake, Head of Engineering, Atlantis Resources Ltd

Jeremy Thake has been working in tidal energy for nearly 20 years, across design, site survey and modelling, permissions, engineering design and manufacture, installation and testing. He began as project manager with ITPower on the Seaflow turbine, at Lynmouth in the Bristol Channel, and then moved to the newly-established Marine Current Turbines on the Seagen turbine installed in Strangford Lough. He joined Tidal Generation Limited at an early stage as Engineering Director and worked on both the 500kW and 1MW DeepGen turbines. He was part of the IEC committee for the Tidal Energy Performance technical standard TS 62600-200. Since joining Atlantis as Head of Engineering in 2012, he has led the design of the AR1500 turbine that is now operating as part of the MeyGen project off the north coast of Scotland.

Abstracts: Session 1

Performance Optimization of a Coaxial-Cylinder Wave Energy Converter

P. Jin, B. Zhou, Z. Chen, L. Zhang
Harbin Engineering University

As water waves become an important source of renewable energy, various wave energy converters (WECs) are deviced. A heaving coaxial-cylinder WEC [1] shows potential of high efficiency and reliability. Optimization of the WEC performance is a key process. In the previous studies [2-3] only generator damping is concerned (denoted as suboptimal operating condition, or SC). Our main goal is to extend the optimization process considering generator stiffness (optimal operating condition, or OC). The coupled dynamics of a two-body model is analyzed in frequency domain using a method analogous to that in [4] but with a refinement to suit our case. The purposes are to search for the optimal capture width ratio for each wave frequency and to observe the global trend. The hydrodynamic coefficients, added mass and radiation damping, of the two cylinders are calculated using the commercial software HydroStar. The results are validated. The performance of the WEC in both SC and OC in a wave frequency range from 0 to 5 rad/s is studied for comparison. For the capture width ratio in SC, between the two peaks due to the respective resonanct motion of the two cylinders [3], a third peak associated with a joint resonant phenomenon is found as the two cylinders nearly heave as one body with the presence of a large generator damping. In OC, the capture width ratio pattern becomes two smoothly descending segments with a gap in between, while the generator damping and stiffness vary almost linearly with the wave frequency. The value of the capture width ratio is globally larger in OC. The two-segment pattern makes the WEC more adapted in varying sea conditions and it is not hard to achieve by tuning the generator parameters according to the incident waves. This study contributes a knowledge to design the generator system.

[1] Son, D. and Yeung, R. W. (2014). Performance predictions and validation of a two coaxial-cylinder system as a wave-energy extractor. In ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering, pages V007T12A027-V007T12A027.

[2] Son, D., Belissen, V., and Yeung, R. W. (2016). Performance validation and optimization of a dual coaxial-cylinder ocean-wave energy extractor. Renewable Energy, 92:192-201.

[3] Wang, L., Son, D., and Yeung, R. W. (2016a). Effect of mooring-line stiffness on the performance of a dual coaxial-cylinder wave-energy converter. Applied Ocean Research, 59:577-588.

[4] Liang, C. and Zuo, L. (2017). On the dynamics and design of a two-body wave energy converter. Renewable Energy, 101(1):265-274.

Wave Slamming on a Flap-Type Wave Energy Converter

E. Renzi[1], Y. Wei[2], F. Dias[3]
[1]Loughborough University, [2]University of Groningen, [3]University College Dublin

This project aims to determine the maximum impact pressure exerted by wave slamming on an oscillating wave energy converter. Slamming is the violent interaction between a solid body and steep water waves impacting on it [1]. Previous experimental investigations have shown the occurrence of wave slamming on a flap-type wave energy converter in highly energetic sea states, which can undermine the survivability of the device. Computational fluid dynamics models developed to better understand the phenomenon were able to reproduce the general impact dynamics, but underestimated the peak pressure by a factor 10 [2]. In this project, we derive a mathematical model based on the pressure impulse theory originally devised by Cooker & Peregrine [3], which takes into account the effects of air entrapment. The model is based on a conformal mapping technique and is successfully validated against available experimental data. Parametric analysis shows that the maximum pressure impulse depends strongly on the flap inclination at impact, and less strongly on the position of the contact point before impact. Aeration effects are also considered. We show that air entrapment enhances the pressure-impulse values at all points along the flap. Our mathematical expressions can be calculated very quickly with a commercial mathematical software and therefore are instrumental to structural engineers designing flap-type converters.

[1] Dias, F., Ghidaglia, J.-M., Slamming: Recent progress in the evaluation of impact pressures, Annual Review of Fluid Mechanics, 50 (2018): 243-273.

[2] Wei, Y., Abadie, T., Henry, A., Dias, F., Wave interaction with an Oscillating Wave Surge Converter. Part II: Slamming, Ocean Engineering, 113 (2016): 319-334.

[3] Cooker, M., Peregrine, D.H., Pressure-impulse theory for liquid impact problems, Journal of Fluid Mechanics, 50 (1995): 193-214.

Abstracts: Session 1

Nonlinear Model of Curved-Shape Oscillating Wave Surge Converters

S. Michele, E. Renzi
Loughborough University

We present a nonlinear theory for an Oscillating Wave Surge Converter (OWSC) in a semi-infinite bidimensional channel [1-2]. The gate model is a vertical surging plate, with a weak horizontal deviation of the wetted surface about the vertical plane. The length scales of the free surface elevation, the gate vertical displacement and the horizontal oscillations are assumed small if compared to the channel depth. Therefore, the boundary conditions on the gate and on the free surface can be expanded respectively about the vertical and the horizontal mean free-surface level. Perturbation-harmonic expansion of the variables up to the second order allows us to decompose the nonlinear governing equations in a sequence of linear boundary-value problems of order n and harmonic m (see also [3-4]). We show that the gate shape appears as a forcing term for the first-harmonic solution at the second order, while the second order drift and the second-harmonic component result to be independent on the gate profile. Then, we derive the expressions both for the generated power and the capture factor taking into account second-order contributions. We finally show that hydrodynamic interactions between the curved gate and short waves can have either constructive or disruptive effects in terms of power absorption.

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Optimisation of WEC-type Floating Breakwaters

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Aims & Objectives**:** To validate and use a novel computational fluid dynamics (CFD) modelling method for the numerical analysis of the hydrodynamic performance of varying cross-sectional geometries of a pile-restrained floating breakwater wave energy convertor (WEC) [1].

Methods**:** A novel Particle-in-Cell (PIC) CFD modelling method [2] was validated against published experimental data obtained from physical wave flume testing of the hydrodynamic performance of a pile-restrained, floating breakwater WEC. The power take-off (PTO) and wave attenuation performance was analysed over a range of wave periods, drafts and wave heights. The model was then applied to assess the wave transmission coefficient (Kt) and capture width ratio (CWR) [ratio of captured energy and wave energy] of a variety of cross -sectional geometries of the modelled WEC-type floating breakwater.

Results: Kt and CWR for a variety of cross-sectional geometries were obtained, as shown in Fig 1, where the excitation current controls the PTO damping force. This demonstrates varying effectiveness in CWR and in distal wave attenuation. In Fig 1, it can be seen that at the extremes of geometry, rectangular box geometry was associated with optimal wave attenuation but least efficient PTO, whereas semi-circular geometry has relatively poor wave attenuation characteristics but more efficient PTO. Decreasing radius of curvatures applied to a box geometry were found to improve wave attenuation but at the cost of decreasing CWR. Analysis identified a geometry (box-type with small curve corners 12.5% of box width) that optimally balanced the dual functions of wave energy conversion and distal wave transmission attenuation.

Conclusions: The described PIC CFD method can effectively analyse the optimal geometry of WEC-type floating breakwaters. The method allows accurate calculation of Kt and CWR, and identifies an optimal cross-sectional geometry. The PIC method shows great potential for the further optimisation of the efficiency of WEC-type floating breakwaters.

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Abstracts: Session 1

An Optimization Approach of a Wavesub Array

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Results are presented for a method of optimization as part of a project to optimize the LCOE (in arbitrary unit) of a WaveSub device [1] in an array configuration. An array is analyzed because it could improve the cost of energy when compared to a single device. The numerical dynamic model of WEC-Sim was simulated in the time domain in a previous project and validated against tank testing results from Plymouth University's Ocean basin [2]. In particular this step was necessary to ensure the validity of the optimization result.

Nemoh [3] is used for hydrodynamic computation and the standard linear potential flow formulation is employed without the use of simplifying approximations for array interaction. Second order dynamic boundary conditions are neglected including drift force for example. MATLAB [4] and the open-source WEC-Sim [5] are used to find the energy production of the device. The Power Take-Off and the mooring force are linearized. The PTO is simplified as a spring-damping system while the mooring is modelled as a spring system. Viscous drag is approximated using a drag coefficient but work is ongoing to identify suitable values for these coefficients.

The optimization is extended to optimize for a metric reflecting the LCOE. Different design parameters are optimized based on the WaveSub system: the float spacing and number, the float-reactor separation and the PTO tuning. The optimization proposed is quite computational demanding especially if applied to a large WEC array. Consequently, the WEC number is limited to a small number (<10) to avoid a long computational time.

Finally, an optimization algorithm combined with a parallel computing simulation is conducted to reduce the simulation time of the optimization process. Outputs from the model provide device designs with the most cost effective energy production.

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A Wave Energy Converter for Small Communities: Numerical Modelling of a Compliant Power Take-Off

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In this study, the feasibility of small, "low-tech", near-shore Wave Energy Converter (WEC) concepts for use by coastal communities in Less Developed Countries was investigated. Such devices inevitably operate at lower efficiencies than large WECs in more energetic offshore environments, but if cheap and simple enough to be community built, operated and maintained, they could represent a low-carbon alternative to small petrol/diesel generators, especially where fuel supply is irregular.

One of the simplest WEC concepts is that of a point absorber coupled to a piston/cylinder Power Take Off (PTO), pumping water to an onshore header tank that feeds a turbine. However, the integrity of sliding contact piston seals and surface finish/tolerance of the cylinder bore can be problematic for community manufacture/maintenance. An alternative PTO is a flexible (rubber or similar fabric) pump; examples include bellows, diaphragms or concertinas. They have no sliding contact seals or finely toleranced components. Such PTOs present a challenge in numerical modelling; they are compliant so that the volume pumped on each stroke is affected by the internal chamber pressure acting to elastically expand the chamber. This work has developed a mathematical model of a compliant PTO, incorporated into a Rigid Body Solver coupled with a Boundary Element Method code. The numerical model was experimentally validated at Plymouth University's COAST facility.

Frictional losses and fluid inertia in the pipe from WEC to shore strongly influence the device behaviour. Modelling revealed that the inertia in the pipe could be used to advantage, leading to a state where more fluid is pumped than the swept volume of the pump. This "inertia-driven flow" results from the deceleration in the pipe near the end of the stroke, causing low chamber pressure. This opens both pump inlet and outlet check valves together, resulting in free flow towards the header tank.

Abstracts: Session 2

Beyond OC5 – Further Advances In Floating Wind Turbine Modelling With Bladed

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DNV GL

Accurate numerical modelling of floating offshore wind turbines is of upmost importance given its prominence in the design process. Activities carried out under the Offshore Code Comparison Collaboration Continuation with Correlation (OC5) project [1] have validated various numerical tools against experimental tank test data, as collected at MARIN on the DeepCwind semi-submersible concept test model. One of these tools was the aero-hydro-servo-elastic modelling package 'Bladed'. The Bladed results comparison with the experimental data was amongst the best of any of the codes involved, however, in common with many of the participants using a Boundary Element Hydrodynamic approach, certain loads were underestimated, and some low frequency excitation was not captured in the numerical simulations. Following the completion of the OC5 project, new features have been implemented in the original DNV GL OC5 model. This paper describes the implementation and results of new comparisons incorporating these additional modelling features.

For the new comparisons presented here, a number of further updates to the turbine model and simulation settings were implemented in Bladed. Additionally, further results were obtained using an enhanced hydrodynamic modelling approach based on the instantaneous position of the floating platform structural mesh, calculated at each time step. Selected load cases from the OC5 study have been chosen to perform the comparison.

Simulation Methodology of Floating Offshore Wind Turbine (FOWT) Platforms with Porous Outer Layers using OpenFOAM

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Floating Offshore Wind Turbines (FOWTs) are a promising source of renewable energy, as they avoid NIMBY criticism and can profit from stronger and less intermittent winds offshore. However, they have their own engineering challenges, particularly in developing a platform, which will be stable under operational and extreme conditions including wind and wave effects. Within the ResIn (Resilient Integrated-Coupled FOW platform design methodology) project, a framework to model the complex system of a FOWT using the opensource CFD software OpenFOAM is being developed. Some of the main challenges to consider in the modelling process are: wave generation and absorption, wave structure interaction (WSI), resolution of the computational mesh, an appropriate meshing technique using the 6DOF floating platform, effects of the mooring line interaction, effects of the wind and wind turbine interaction. The project is in general more about developing a methodology for CFD simulations rather than supporting the design of any specific FOWT.

An aspect of the ResIn project is to investigate the potential to reduce the wave forces on the platform by attaching a porous shroud around the outside of the platform. Therefore, a volume-averaged Reynolds-averaged Navier-Stokes (VARANS) approach is used to implement porous zones in a macroscopic manner. A series of simulations are presented building up from simple to more complex, as follows: WSI with a fixed cylinder, WSI with a solid wall, WSI with a perforated wall, WSI with a perforated and solid wall. At present, regular waves are used for all simulations. Later on, the project will investigate extreme wave conditions, include mooring line interactions and wind and wind turbine effects. In the domain where potential-flow-theory applies, the CFD results are verified analytically and with solutions from an in-house BEM code.

Abstracts: Session 2

A CFD Analysis of the Aerodynamics of a Floating Wind Turbine

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Floating offshore wind turbines present unique challenges in terms of their design due to the combined wind and wave loading and resulting platform motions to which they are subjected. This leads to increased fatigue and unsteady aerodynamic behaviour [1]. The use of computational fluid dynamics (CFD) for simulation and analysis of floating wind turbine aerodynamics is becoming increasingly popular since it allows for the modelling of complex flow phenomena and their impact on floating wind turbine aerodynamics that cannot be accurately captured by simpler methods [2].

The presented work will use the CFD toolbox OpenFOAM to analyse the aerodynamic characteristics of a floating wind turbine, represented by a validated actuator disk model. The environmental conditions for normal operation and extreme cases will be simulated by a suitable boundary layer model. This work aims to use the results of this analysis to optimise the design of the blades of a floating wind turbine and ensure its survival in extreme environmental conditions occurring in storms and typhoons.

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Appraisal of an Intelligent Mooring System for Floating Offshore Wind

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Currently seabed fixed offshore wind turbines are limited to water depths of approximately 50 m due to the cost and technical challenges associated with deeper installations. There have, however, been a number of floating offshore wind turbine (FOWT) deployments at depths greater than this [1], [2]. This type of technology could be key to accessing offshore sites that were previously deemed infeasible, at locations in which the wind energy resource also tends to be greater.

The mooring system for a FOWT directly influences the platform stability and is critical to its safe station keeping and survivability. FOWT installed to date have used conventional mooring line materials, e.g. chain, where the cost is proportional to the minimum breaking load (MBL). Therefore, if peak loading can be reduced in the mooring system, so too will its cost. The mooring system has been identified as one of the key technical barriers that could deliver considerable cost savings in FOWT [3].

This presentation introduces a mooring system in which the axial stiffness, and hence line tension, can be actively controlled, referred to as the intelligent mooring system (IMS) [4], [5]. The IMS is a hollow braided rope in which a flexible water filled bladder is housed. The pressure inside the IMS can be controlled to alter the stiffness of the mooring line. This active control enables the characteristics of the mooring system to become variable in operation to suit the prevailing metocean conditions, a feature not possible in conventional mooring designs.

The capabilities of the IMS system have been evaluated through coupled FAST-OrcaFlex simulations of floating wind turbines. This type of model allows the wind turbine to be modelled in FAST, while the platform and mooring lines are modelled in OrcaFlex. Simulations were run to compare the system dynamics with and without the inclusion of IMS. Results with IMS suggest an appreciable reduction in mooring line loads, while it is also possible to improve turbine performance through the minimization of undesired platform motions.

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Abstracts: Session 2

Multi-Objective Optimization of Mooring Systems for Offshore Renewable Energy Devices

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Optimization algorithms have been deployed for a range of renewable energy problems and can successfully be applied to aid in the design of devices, farms, control strategies, and operations and maintenance strategies. Building on this, the present work makes use of a multi-objective genetic algorithm (GA) in order to develop a framework that can further aid in the design and development of offshore renewable energy systems by explicitly taking into account reliability considerations [1]. Though the reliability-based design optimization approach has previously been used in offshore renewable energy applications and multi-objective optimization applications, it has not previously been applied to multi-objective offshore renewable energy design optimization. As the offshore renewable energy sectors grows it is important for the industry to explore more sophisticated methods of designing devices in order to ensure that the device reliability and lifetime can be maximized while downtime and cost are minimized.

This work describes the development of a framework using a GA in order to aid in the design of a mooring system for offshore renewable energy devices. This framework couples numerical models of the mooring system and structural response to both stress-life cumulative damage models and cost models in order for the GA to effectively operate considering the multiple objectives. The use of this multi-objective optimization approach allows multiple design objectives such as system lifetime and cost to be satisfied simultaneously using an automated mathematical approach. From the outputs of this approach, a designer can then select a solution which appropriately balances the different objectives. The developed framework will be applicable to any offshore technology subsystem allowing multi-objective optimization and reliability to be considered from the design stage in order to improve the design efficiency and aid the industry in using more systematic design approaches.

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Abstracts: Session 3

Theoretical Power and Energy Estimation of the Tidal Range Resources in the Northern Gulf of California, Mexico

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The Gulf of California (Mexico), represents a potential area for marine tidal-range energy exploitation. In the northern part of the Bay, the tidal-range is over 6 metres [1]. The aim of this work is to quantify the theoretically available extractable tidal-range energy in the northern part of the Gulf of California. For this study, a depth-averaged 2D Barotropic model is used [2], revealing that the tidal range has a maximum height of 7 metres whilst the mean tidal range is around 5 metres in the study area. The theoretical instantaneous power indicates a maximum instantaneous power density over the spring period between 120 and 200 kW/m2 in the northern region of the Gulf. Furthermore, the annual predicted maximum power density is estimated to be 200 kW/m2 to 350 kW/m2, whilst the mean annual power density is around 100 to 140 kW/m2. Additionally, the annual net power density indicates the total energy value exceeds 1000 MW/m2 where the maximum tidal range is approximately 7 metres. Therefore, this study proposes three potential zones for tidal-range energy generation in the northwest of the Gulf of California, at: (1) near San Felipe port, (2) Upper Colorado River and (3) in the Gulf of Santa Clara. Although, there is a considerable energy resource in the Northern-Gulf [3], barrage or lagoon build-projects would need to consider the suitability of the Mexican electricity network at those specific locations [4].

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Optimisation of Tidal Turbine Blades with Winglets

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Tidal turbines have been deployed worldwide at a scale expected to be the commercially competitive size. Present costs per installed capacity are understandably high and therefore there is a need to reduce the cost of energy via means outside of the expected economies of scale that mass manufacturing will provide. Increasing the efficiency of energy capture can be achieved by changing the geometric properties of the blades. This work investigates and quantifies the effect of modifying the blade tip geometry via winglets that seek to reduce blade tip losses and enhance the local flow across the blades.

Winglets are now commonplace on commercial aircraft and are relatively easy to design and quantify changes to performance of non-rotating applications. Winglets have been used on wind turbines since the 1990s [1]. ENERCON is probably the only large manufacturer that has exploited the potential of winglets. An enhancement of 12% to 15% was achieved in their E-126 model by a refinement of the airflow around the nacelle and the addition of winglets at the blade tips [2]. Understandably, details of the design and development are not of public domain.

Only a handful of experiments have been publically available regarding winglets for tidal turbines. Zhu et al. [3] used power and thrust measurements of a horizontal axis marine turbine taken at the University of Southampton [4] to have a baseline for their numerical model that was used to simulate the addition of winglets. The best design produced a higher tip speed ratio and yielded a maximum power increase of 3.96%.

This paper describes experiments using a 1/20th scale three-bladed marine current turbine, with the hydrofoil geometry provided by the company Atlantis Resources Limited. Power and thrust measurements of the rotor were made for a range of tip speed ratios and for different blade tips.

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Abstracts: Session 3

Tidal Stream Turbine Configurations for Low Speed Flow

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Based on the electricity demand forecast [1] for Costa Rica, the renewable energy options are running short, therefore a lookout for marine energy alternatives has been done. Initial studies [2] have shown that some areas of the country have potential for the production of electricity, yet a more in depth resource characterization was recommended to determine the real values of the available power in the country. This research is based on the initial values obtained for potential locations where the tidal resource could be used, but with low velocities (<2m/s). The aim is to determine if it's possible to modify a well characterised horizontal axis tidal turbine (HATT) and optimise it to operate in low speed flow (1.2 m/s).
Using ANSYS CFX as the CFD modelling tool, CMERG's well characterised three-bladed turbine is the reference for a comparison between the new turbine configurations. Solidity [3] is the driving variable for the two variation cases made to the turbine, both of them having turbines with two, four and five blades.

One case consists of increasing/reducing the solidity by changing the number of blades of the original turbine, using its unmodified profile[4] . The second case consists of keeping the solidity constant, whilst the number of blades is changed, varying the chord length of the original turbine blade.

With the results of the simulations, an 'optimum' configuration to operate in low speed flows is selected. The approach can provide a method to adapt turbines, that have been designed for hig speed flows, to work in lower velocity conditions.

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Design Process for a Scale Horizontal Axis Tidal Turbine Blade

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With the UK aiming to have 15% of all energy produced coming from renewable sources by 2020 [1] developing commercially viable renewable devices is of high importance, and marine energy could play a large part in achieving this goal. With such high potential from our coastlines the necessity to develop durable and efficient devices means emphasis must be placed on the design of the blades to maximize the performance if the devices.

Cardiff University has been using the Wortmann FX63-137 aerofoil [2] for its blade design, this profile was used as it has low stall and high lift characteristics [3]. Development of a new turbine led to redesigning the blade whilst maintaining the Wortmann aerofoil. Changes to the blade twist, chord length and the root-hub attachment were to be looked at. In addition to these design requirements the *CP* was to be greater than the original design and the *CT* was not to be significantly increased.

This paper describes the design stages utilising both Blade Element Momentum Theory (BEMT) code developed at Strathclyde University [4] and the Computational Fluid Dynamics (CFD) package ANSYS CFX. The fundamental blade design started with the original blade and morphed using the BEMT code. CFD was then used to model the blade and the hydrodynamics.

A comparison between the results for the BEMT and the CFD models showed good agreement. The final design resulted in a reduced twist distribution, a modified chord length and the use of a symmetrical aerofoil at the root to provide the necessary width for the hub attachment. The C_p was found to have increased to *0.45* from *0.42* [5] and the maximum C_T was *0.9.* The CFD model was developed to include the stanchion which had previously been ignored to allow for a closer comparison to the BEMT model.

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Abstracts: Session 3

Wave-Current Numerical Modelling Using Stokes 2nd-Order and Linear Wave Theory

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A Tidal Stream Turbine (TST) can extract more energy near the surface of the water [1], where the oscillatory effects produced by waves also have the greatest effect. Waves induce orbital motions which add horizontal and vertical components to the current flow, penetrating the water column by up to half their wavelength [2]. Laboratory scale TST testing has been carried out by [3], [4] & [5], to evaluate the effects of wave-current interaction with a TST and [6] looks specifically at the blade loading magnitudes with respect to the relative position of the turbine blade and the wave peak/trough. In conjunction with laboratory testing, Computational Fluid Dynamics (CFD) is used to investigate the dynamic loading experienced by a TST in the presence of current and waves. In order to quantify the performance of a TST, it is critical that the effects of wave-current interaction are assessed, along with turbulence and structural interference.

Work reported here will focus on the development of a wave-current numerical model using ANSYS ICEM and CFX. It will detail the specific mesh properties required while comparing with [7], [8] & [9], as well as looking at setup specifics, vital to developing a realistic free surface wave-current model. Comparison is made between Linear Wave Theory (LWT) and Stokes 2nd Order Theory as well as looking into intermediate and deep-water waves. Experimental wave data will validate the numerical model developed for this study.

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Distortion of Tidal Flow Turbulence Incident on a Horizontal Axis Tidal Turbine

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Comparisons will be shown between computational predictions and experimental measurements of the distortion of turbulence in a stream incident on a horizontal axis tidal-stream rotor. Rapid Distortion of Turbulence (RDT) theory is shown to predict that distortion by the mean flow field of the rotor can lead to appreciable intensification of the streamwise turbulent velocity and hence the unsteady loading of the rotor blades. The mean flow field of the rotor which causes the distortion is represented in the theory by the one-dimensional actuator disc theory of Froude, Betz and Joukowski. When the turbulence length scale is small compared to the rotor diameter the classical analysis of Batchelor and Proudman [1], as further developed by Durbin [2] for a non-homogeneous axisymmetric flow, is used to compute the distortion of the incident turbulence impacting the swept disc of the rotor. In the more usual case that the incident turbulent length-scale is not small compared with the rotor diameter numerical integration over wave number space following the approach of Hunt [3] is used to compute the distortion of the axial component of the turbulence on the rotor axis with estimates for the rest of the disc. These results provide the main correction for the incident velocity boundary condition at the rotor usually used to calculate unsteady loading on a rotor operating in turbulence. The presentation will show how they can be combined with an analysis of experimental data carried out by Milne [4] which gave an assessment of typical intensities, spectra and length-scales of the turbulence in a tidal stream through the Sound of Islay, to provide estimates of the likely magnitude of the distortion of the turbulence in this channel by a horizontal-axis tidal-stream rotor of typical size.

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Abstracts: Session 3

Modelling the Tidal Stream Energy Resource in Indonesia

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The tidal-stream energy resource of Indonesia holds vast potential [1], but also brings new challenges beyond the shallow, well-mixed sites currently being developed. The archipelagic nation lies between the Indian and Pacific Oceans, divided by a number of interconnected shallow seas. Topographical elevations range from the tens of meters to the thousands and the tides around Indonesia are a complicated mix of diurnal and semi-diurnal tides [2]. The resource potential of some of the Indonesian tidal straits (i.e: the Alas Strait [3]) has been investigated and show promise for tidal stream energy development. The oceanic current, called the Indonesian Throughflow, connects the Indian and Pacific Oceans through some of the tidal straits, controlling the exchange of ocean waters and enhancing the tidal currents in some regions [2]. The complex oceanography of Indonesia leads to challenges in resource assessment. For example, resource assessments in shallow sea regions have historically been undertaken using depth averaged ocean models. In regions, like Indonesia, where deep water and baroclinic flows are present, tidal energy resource assessment may require 3-D approaches [4]. In this study, a 3-D resource model for an energetic tidal strait in Indonesia is developed using the Regional Ocean Modeling System (ROMS), with a 3-D energy extraction term, forced with HYCOM ocean current data, GEBCO bathymetry and TPXO barotropic tidal data. The available theoretical tidal-stream energy resource is estimated, including the interaction of the Indonesian Throughflow and the resource. Uncertainties in resource assessment will also be discussed (e.g. lack of validation data and high-resolution bathymetry).

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Abstracts: Session 4

Offshore Energy Planning Provisions and Transnational Maritime Spatial Planning in the North Sea Region: Findings from the NORTHSEE Project

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The North Sea is one of the busiest seas for maritime industries in the world. Its shared resources represent a crucial asset, but also a shared territorial challenge to North Sea Region (NSR) countries, including Belgium, Denmark, Germany, Netherlands, Norway, Sweden, and the United Kingdom (England and Scotland). Various maritime sectors, such as offshore energy, play a major part in generating economic value and employment and are set to expand in line with smart 'Blue Growth' objectives. Given the transnational nature of offshore energy activities and the transnational character of most marine ecosystems, facilitating greater transnational coherence and cooperation in marine planning represents a key shared challenge. The European-funded NorthSEE project addresses this challenge directly.

The NorthSEE project promotes a better exchange of information among NSR marine planning authorities and related experts and institutions. The project aims at achieving greater coherence in MSP across the NSR for three topics of transnational nature: environmental aspects, shipping routes, and energy infrastructure. Here, the focus will be offshore energy planning provisions, the sustainable development of offshore renewable energies, related offshore grid infrastructure, and relevant transnational marine planning aspects in the NSR. We will present an overview of the state-of -the-art offshore energy planning provisions for the production and transportation of energy in the North Sea, including:

• The existing international MSP institutional framework in the NSR, including past and current experience of transnational energy cooperation between North Sea countries;

• An overview of short- (2020), mid- (2030), and long- (2050) term national and transnational energy planning provisions, including energy objectives, policies, and planning areas; and

• Future trends in the offshore energy policy landscape and industry developments across the NSR.

The outputs from the NorthSEE project are aimed at maritime planners and other bodies to help facilitate greater transnational coherence and cooperation in maritime planning.

Cost Reduction in Tidal Stream Energy Through Operational Modelling

S. Jermy
James Fisher Marine Services Ltd

Recent work by the offshore renewable energy catapult has indicated potential cost reduction paths in levelised cost of energy (LCOE) for tidal stream energy. A key factor in offshore renewables LCOEs is the cost of marine operations, including the charter cost of vessel and subsea construction equipments. This is particularly the case for high energy tidal stream sites, which are amongst the most demanding offshore construction environments in the world. The added complication is offshore meteorology, which routinely causes offshore delays, increases CAPEX costs, and thus increases LCOE. Modelling the impact of oceanography and meteorology on the time and cost of the marine operations should thus play a key part of the design and development process for construction vessels and subsea equipments for the offshore renewables environment. By using marine operations modelling software, such as Mermaid®, it is possible to assess the impact of key design parameters upon offshore installation times and costs and, thus, LCOE. The impact can be assessed at the conceptual stage, using real environmental hindcast data, thus allowing the design, development and procurement of systems that are optimised to reduce LCOE. A case study, using data from the Pentland Firth, shows that tidal stream LCOE reductions of over 50% against current figures could be possible through the use of innovative vessels and subsea equipments. The same analytic approach should be applicable to the full range of offshore renewable energy technological design and development.

Abstracts: Session 4

Decommissioning of the Ex-TGL Tidal Turbine Tripod

T. Warren
Blackfish Engineering Design Ltd

EMEC are in the process of removing the sub-sea tripod foundation that was installed in 2009 and subsequently used by Tidal Generation Ltd for two tidal stream turbines. This project aims to complete forensic examination of the removed tripod and to provide learning and lessons for the tidal and wider marine renewable industries, focussing on biofouling and corrosion effects due to prolonged seawater immersion.

The work will be completed by a consortium as part of a FORESEA funded project, using the following partners:

- Blackfish Engineering Design will coordinate the planning, complete visual inspection and condition reporting, collate images and lessons learned report.
- Heriot Watt University International Centre of Island Technology will provide specialist biofouling expertise and will conduct the submerged tripod biofouling survey.
- Brunel University Centre for Advanced Solidification Technology will provide specialist metallurgical investigation equipment and expertise.

The works will include diver and ROV surveys of the tripod to record the different species of biofouling and their prevalence as well as the distribution of biofouling on different parts of the tripod. Once removed from the water and cut up, metallurgical analysis of samples using visual and microscopic techniques will determine effects of corrosion, examine high fatigue loaded welds and regions of high stress gradient.

Other features such as electrical connector condition, electrical splice box sealing, anodes and flange condition, paint performance and galvanic corrosion will be inspected and recorded.

The objectives are to develop and validate a process of data collection to obtain an understanding of the end of life condition of Ocean Energy Converter subsea infrastructure, develop guidelines and best practice, and to disseminate the data to the industry and research communities.

The tripod will be removed in April / May 2018 so it is hoped to be able to present results at the PRIMaRE conference in July.

FaBTest — A Nursery Site for Marine Renewable Energy Devices

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University of Exeter

Falmouth Bay Test site (FaBTest) is an award-winning, pre-consented, 2.8km2 test area situated within Falmouth harbour. This nursery facility enables developers to test marine technologies, components, moorings and deployment procedures in a moderate wave climate, whist giving excellent accessibility to the device and benefitting from extensive nearby port infrastructure. Due to the success of the site to date, FaBTest continues to attract a broad spectrum of innovative marine technology developers, including Marine Power Sytsems (MPS) Ltd, who will deploy later this year.

FaBTest's pre-consented status aims to provide a fast, flexible low risk and low cost solution for the testing of marine energy technologies, components, moorings and deployment procedures. The site offers water depths of 20m-50m and seabed types of rock, gravel and sand. Operational support of the site, as well as ongoing monitoring and world leading research is provided by the Renewable Energy Group from the University of Exeter.

The site became operational in October 2011 and the Fred Olsen 'Lifesaver' device was the first machine deployed on site; commissioned in March 2012 and on site for 26 months. Following a successful period of prototype development in Cornwall, the device is now at the Wave Energy Test Site in Hawaii, and will be imminently deployed and grid connected for the next stage of technology demonstration. In 2015, Polygen deployed their Volta device on site. The Cornish supply chain was heavily involved with the development of the mooring spread as well as installation and maintenance of the device on site. Summer 2018 will see MPS Ltd deploying their WaveSub device on the FaBTest site. This novel quarter-scale device is designed to be modular for commercial upscaling and will undergo a rigorous testing programme to validate numerical models and optimize design.

Abstracts: Session 5

Test of a Fylfot-Shaped Wave-Energy Generator

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It has been proposed that rotationally-symmetric rotors, such as those in the shape of a fylfot, might rotate towards their arm-tips when subjected to random wave fields, due to a sheltering-damping effect [1]. This suggests the possibility of a simple and elegant wave-energy generator. Here, we report on experimental tests of this proposal using fylfot-shaped rotors subject to random and plane waves. Two sizes of rotors were used: a small-scale polymer 3-D printed model, 80mm in diameter with 3mm thick arms and a larger aluminium model, 800mm in diameter with 3mm thick arms. The former was tested in a tank on a shake table and showed consistent motion towards the arm tips, as predicted. The larger model was tested in a wave tank at the University of Plymouth COAST Lab and also showed a rotation towards the arm-tips, as predicted, for waves of wavelengths roughly equal to the spacing between the arms. An unexpected result was that the rotation became larger for waves longer than the spacing between the arms. The results confirm that the proposed device is a viable wave-energy generator.

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An Accurate and Cost-Efficient Physical Scale Model of a Direct Driven Point-Absorber with Constant Damping Power Take-Off

S. Thomas[1], M. Giassi[1], M. Göteman[1], M. Eriksson[1], J. Isberg[1], M. Hann[2], E. Ransley[2], J. Engström[1]
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When it comes to validating simulation results for wave energy converters, physical scale experiments play an important role as a cost effective preliminary stage before full-scale test. But modelling the power take-off for scale models can be a complex process. State-of-the-art models use static friction [1] or controlled motors [2-4] to simulate the behavior of the actual power take-off generator. In simulations of an idealized generator, a constant velocity-proportional damping is often used. Controlled motors can operate this way but are relatively complex and expensive and may suffer from uncertainties in the friction present or are limited by the motor dynamics [4]. In particular when physical models are compared to simulations, a well parametrised model is invaluable. The model proposed here uses an eddy current break to provide a constant velocity dependent damping: Permanent magnets generate a magnetic field in which an aluminum disc, accelerated by the force acting on the buoy, rotates. Weights attached to the disc with a rope generate a moment opposed to the buoy force.

The system is able to provide a constant damping, while being nearly frictionless. The motion of the PTO is measured using an accelerometer, acting as a high precision position measurement system.

The results of 1:10 wave tank tests are compared to a numerical model based on linear potential wave theory, with good agreement.

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Abstracts: Session 5

Laboratory Tests of a Novel Hybrid Wind-Wave Energy Converter

C. Perez-Collazo, D. Greaves, G. Iglesias
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Multipurpose platforms have been proposed as a sustainable approach to harnessing different marine resources and combining their use under the same platform [1]. Hybrid wind-wave systems are a type of multipurpose platform where a single platform combines the exploitation of offshore wind and wave energy [2]. In particular, this research deals with a novel hybrid wind-wave system that integrates an oscillating water column (OWC) wave energy converter (WEC) with an offshore wind substructure [3]. The main objective of this work is to define and test a simplified version of this hybrid device by means of physical modelling. The tests were undertaken considering: (i) monochromatic and random waves; and (ii) different damping conditions (i.e., using different orifice diameters) . In all the conditions, the differential air pressure between the inner OWC chamber and the atmosphere, the free surface oscillation inside the chamber, and the wave field in the vicinity of the model were recorded. On the basis of the data from the experimental campaign, the hydrodynamic response of the WEC sub-system is characterised following [4]. The results from this multifaceted analysis led to the proof of concept of this novel hybrid system; but also the characterization of its behaviour and interaction with the wave field, essential to fully understanding the benefits of hybrid systems.

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Use of HF Radar for Replicating Complex Wave Conditions for Testing of Wave Energy Converters

D. Wang, D. Greaves, D. Conley, M. Hann, K. Colins
University of Plymouth

Wave tank testing is a commonly used way to assess the performance of Wave Energy Converters (WEC). Environmental data collected for testing can be obtained by different instruments, such as buoys, ADCP, HF radar etc. The widely accepted way to re-create the environmental condition is to simplify the data collected and get the parametric wave spectrum, such as JONSWAP spectrum or Pierson-Moskowitz spectrum, then reproduce it in the wave tank. However, this kind of parametric spectrum is a simplified numerical model which omits much useful information, such as the directional information of wave and current information and many other details. It is widely known that the current will have effect on the dispersion relationship of the waves. It can affect all the important wave parameters, such as wave steepness, wave length etc.

Today, with the development of HF radar technology, the real-field 3D wave spectrum can be obtained by superposition of scanning areas of two HF radars thus provide an opportunity to re-create the wave-current combined complex condition in the wave tank.

The wave-current combined dataset can be very large, it’s necessary to reduce it to a subset of the representative sea states. In the previous research [1], it did not include the effect of current due to lack of current information, but it is necessary for WEC testing since WECs is in a relatively stationary situation in a wave-current combined condition. By regrouping the data by a wave-current combined metric, it can provide the representative wave cases for tank testing and more accurate responses for WECs.

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Abstracts: Session 5

Applications of Image Recognition Techniques in Hydrodynamic Experimental Testing

R. Pemberton, O. Hill, A. Khan, M. Hann, P. Arber
University of Plymouth

The experimental testing of wave energy converters will typically require the measurement of loads and wave heights. Whilst there is a variety of measurement equipment already available to do so, in both cases the requirement to place a measurement device in a location which is either not readily accessible or may lead to equipment damage often exists. With a view to address this problem, this project investigates the application of optical methods in conjunction with image recognition applied to two measurement systems.

The first measurement system is a load cell manufactured using FDM 3D Printing and a USB microscope. The load cell consists of two cantilever beams which deflect as a tensile load is applied. The deflection is filmed by the microscope, and the video file is processed using OpenCV, a standard computer vision library [1]. The load cell was calibrated on an Instrom tensile testing machine and was shown to be to be linear within their working range. The load cells exhibit a high level of consistency between different force blocks manufactured to the same design.

The second measurement system uses image processing of a laser beam projected through water to infer wave height. Tests were conducted using 1mW lasers and a Digital Single Lens Reflex (DSLR) camera within the University of Plymouth 20m flume. Tests were conducted varying the orientation and relative positions of the camera and laser. Regular waves in the range 0.01-0.03 m amplitude and 0.6-1.3Hz were measured and the data compared to regular resistive wave gauges.

The results show that the existence of open source image processing libraries can allow experimental testers the opportunity to develop their own reliable experimental equipment and obtain measurements which may not have previously been possible, due to either physical or budgetary constraints.

Development of Uppsala's Wave Energy Converter: Optimisation of a Linear Generator

T. Potapenko[1], I. Temiz[1], M. Leijon[1,2]
[1]Uppsala University, [2]Chalmers University of Technology

Surface waves are an alternative energy source, that is still open research area due to the challenges of the field. The concept of a wave energy converter, developed in Uppsala University is robust and simple [1]. Direct power take off mechanism is applied in the system. The mechanical energy of the waves is transformed in electrical one by means of a linear generator, connected to a buoy. Optimization of wave energy converter aims to maximize the power output of the device. In this paper, the damping coefficient is presented as a function of translator velocity. Different damping strategies were reviewed and analyzed in [2,3]. The linear generator is approximated by equivalent circuit, where the resistive load of outer circuit R is subjected to a variation. Pontryagin maximum principle is used in the optimization algorithm [4] to find the maximum value of average power output. Data from Swedish west coast, the wave height and the wave period, are used as an input for the hydrodynamic modeling. Cummins equation is taken for calculation of the body motion in the waves. The optimal value of the resistive load was obtained using Matlab software. Choice of the load resistance will in the future define the armature current.

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Abstracts: Session 5

Development of Uppsala's Wave Energy Converter: Powering a Desalination Plant to Generate Freshwater

J. Leijon, T. Potapenko, I. Temiz, C. Boström
Uppsala University

This presentation gives an overview of the ongoing project at Uppsala University, Sweden, investigating wave powered desalination [1]. The aim of the project is to produce freshwater with the use of renewable offshore energy, as discussed in for example [2][3]. Specifically, the wave energy concept designed at Uppsala University will be discussed. It will highlight the lack of electricity and clean freshwater worldwide [4] and discuss why offshore renewable energy could be an optional solution for water related issues in some regions. A specific case study of a desalination plant located on the Kenyan east coast will be presented. The main study has been carried out using the software Matlab and WAMIT [5] to estimate the power output from the WEC in the region, as well as the possibly desalinated seawater using reverse osmosis (RO) desalination [6]. The research discipline is engineering, but aspects on social, environmental and economic sustainability are included in the study. The main results from the research so far have shown that it is possible to generate freshwater from offshore renewable energy sources, and that coastal regions can benefit from this type of system. That is, wave powered desalination can be a more sustainable option, for remote coastal areas facing water scarcity, than desalination powered by fossil fuels or shipping of freshwater. This suggests that investments and research on this type of collaborative projects, combining questions on electricity and water demand, can be interesting in the future.

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Abstracts: Session 6

Application of Composite Materials to Large, Thick Marine Structures

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Carbon and glass fibre composites are widely used for marine applications such as tidal turbine blades and ship hulls due to their high strength and stiffness, resistance to corrosion and ability to be moulded into complex profiles. However, The implementation of thick composite laminates (100mm+) within these applications leads to numerous challenges relating to design and manufacture. In particular, it is important that the limitations of both the materials and the manufacturing processes are understood by the designer. For large scale composite components, it is unrealistic to assume the manufacturing process can achieve perfect laminates with minimal defects and the design process must ensure that the structures can survive for long lifetimes in seawater environments under highly loaded conditions.

This research addresses two key areas linked to these challenges:

1. Material selection: Ensuring suitable material properties are selected and used in the design. In order to do this, the engineer must consider the long term durability of composite materials in a sea water environment; in particular, the degradation of the composite material due to long term exposure to harsh environments (sea water). This work presents the results of a study investigating accelerated sea water conditioning processes using elevated temperatures to increase the rate of sea water absorption. This study was conducted with various epoxy and vinylester laminates that are suitable for marine use.

2. Manufacturing capabilities: Production cost is a key driver, and so vacuum assisted resin infusion is deemed the most suitable process for manufacturing large, thick composite marine structures of various shapes and curvatures. The selection of this process leads to potential issues including; voidage, excessive exotherm temperatures, shrinkage, warping and fibre wrinking that must be addressed. The realistic and economic capabilities of the manufacturing process must be understood and fed back to the design.

Advanced Design and Manufacture Concept of a Bend-Twist Coupled Wind Turbine Blade

V. Maes, T. Macquart, A. Pirrera, P. Weaver
University of Bristol

The development of wind-turbine technology has been greatly helped by the introduction of glass and carbon fibre based composites. Employing composites materials effectively provides high-stiffness whilst reducing the blades weight, diminishing inertial effects, and providing a means to design larger rotor with reduced cost of energy. For decades, increasing wind turbine sizes has been the principal means of reducing the cost of wind energy. However, as the blade dimensions increase, fatigue and extreme wind events such as gusts have become critical design challenges.

To further increase wind turbine diameters, various load alleviation techniques have been proposed. Passive Bend-Twist Coupled (BTC) blades provide a self correcting aeroelastic mechanism to reduce the variations in angle of attack, hence reducing aerodynamic loads and fatigue. While this approach has been shown, numerically, to be an effective solution, limited experimental validation data are available in the literature. Additionally, the introduction of bend-twist coupling relies on the evaluation of cross-sectional properties for which there is notable uncertainty, and this is considered to be one of the barrier preventing BTC blades from commercial applications.

The current work sets out to resolve this shortage of data by providing a structured set of built and tested demonstrators of various sizes and designs to help build confidence in both the technology and the modelling approaches used to design BTC blades. Alongside the physical demonstrators, shell models will be developed both to aid the design process and to provide additional insight into the performance of the demonstrators. Two bend-twist coupled demonstrators have been built and are about to be tested. Comparisons between the numerical and experimental data for the two first prototypes will be presented at the conference.

Abstracts: Session 6

Study on Mooring Compounds for Offshore Floating Applications

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University of Exeter

The increasing development and evolution of renewable technology projects in offshore sector is one answer to the need for clean energy generation. The current literature demonstrates significant effort to enhance the effectiveness and lower the cost of such investments, through research and development (R&D).

Marine renewable energy (MRE) applications mooring systems constitutes the content of the present study. Moorings for wave energy converters and other floating structures are of crucial importance for these offshore renewable energy applications as they are associated with their station keeping in the severe marine surrounding. Specifically, novel mooring systems have been developed to reducing peak and fatigue loads generated in the system of mooring and to contribute to an increase in the operational life of the mooring.

The present study contributes to the design, deployment and validation of a mooring tether. Laboratory tests of compression forces on specific materials utilized for mooring purposes develop the understanding of these materials` response in the environment are being studied to understand durability of novel mooring systems. Furthermore, parameters analysis with the use of finite element methods (FEM) information are obtained, assessing the influence of different environmental conditions towards the materials behavior within the mooring system. Techniques of numerical modelling allows an in depth approach, reviewing the stress – strain behavior of the materials as well as their displacement from the applied forces.

To progress the design of further tether iteration, the development of an accurate numerical model of this tether is necessary. The accomplishment of this step will be achieved by using a model for a single elastomeric cord. The present work highlights the modelling results of elastomeric core material, making use of physical material tests, which results will be compared to the physical tests and will co-estimated for the development of the full model of the tether core.

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Macro Modelling of Anchoring Systems for Floating Offshore Structures

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Within the context of offshore structures wind and wave energy, geotechnical engineering plays an important role in the anchoring systems for floating devices. So far, no well-established anchor design criterium capable of accurately predicting anchor behaviour for any loading conditions has been developed. The ongoing research developed at the University of Bristol aims to fill this gap by proposing a model for anchors which is able to predict both static and cyclic capacity, cyclic movements (creep), displacement accumulation and anchor trajectory when embedded in cohesive and granular soils. It is based on an existing model which employs principles of classic plasticity theory and was originally developed for suction-embedded plate anchors. The macro-element model under development allows to change anchor and soil type as well as loading conditions. Comparison of the existing model results with testing data were carried out as a starting point for the new model. Ongoing developments on the inclusion of a new plastic potential and consideration of cyclic effects on strength and deformability properties will be presented. The new model will provide an important tool to assist engineers working on the design of floating offshore structures.

Abstracts: Session 6

Application of Spectral Analysis to Predicting the Vertical Conformity and Lateral Resistance of Subsea Cables and Pipes over Rocky Seabeds

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Recent research work by UWA has been investigating the behaviour of cables and small diameter pipes on irregular seabeds with a focus on improving design methods and the integrity of these critical pieces of infrastructure. The research incorporates elements which are investigating pipe-fluid, pipe-seabed and seabed-fluid interactions including boundary layer velocity profiles, near-bed turbulence and the effects these have on pipe hydrodynamics accounting for the effects of gappiness. The research has also included work on predicting the lateral resistance and response of pipes to irregular rocky seabeds under extreme hydrodynamic forcing, such as is found in offshore tidal and wind renewable energy projects.

This paper builds on our previously published work using both experimental and numerical modelling to investigate the lateral resistance of pipes on rocky seabeds. We extend this work to consider the application of spectral methods of characterising seabed profiles to determine the relevant length scales which if present have significant influence on pipe lateral resistance and response. The analysis is supported by comparison to field observations of both seabed rugosity and in-situ cable behaviour to demonstrate the utility and practicality of these methods.

Overall this work will increase the ability of the offshore renewables industry to have positive economic and societal impacts for the UK and internationally, through lower cost and higher supply-security of energy concurrent with reduced carbon emissions. The project will enable more cost-effective and reliable development of marine renewable energy, and will strengthen the competitiveness and capacity of our industry.

Abstracts: Session 7

Development of a Floating Platform for Shallow Water Tidal Stream Energy Resources

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Over recent years the tidal energy sector has seen a turn towards smaller turbines, often combined with a floating platform, with the aim of producing a commercial device that is less capital intensive than megawatt size turbines. Instream Energy Systems have taken this a step further by focusing on a low cost tidal turbine technology suitable for community scale and shallow water resources of 5 to 25 metres water depth.

Under funding from Innovate UK's Industrial Challenge Fund, Instream Energy Systems and a consortium of industry experts are designing, building and testing a full-scale demonstrator to be deployed at in early 2019. The technology consists of a floating catamaran platform to support two multiple units of Instream's proprietary vertical axis rotors which has been designed with the assistance of BAE Systems. The vertical-axis rotor technology makes efficient use of the limited space in the water column by utilising a square swept area, and the rotor's combination with a floating platform opens up vast market potential in the UK and further afield.

This presentation will outline the design process undertaken by the project team and details the design work including concept engineering, load case combinations, hydrodynamic analysis and physical modelling at Plymouth University's COAST laboratory. It will present an initial look at the project results and discuss the world-wide potential for shallow water, small scale tidal turbine technology.

Validation of a Nonlinear, Coupled Numerical Model for Assessment of Floating Tidal Systems

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Floating systems offer an opportunity to expand tidal energy resource through an increase in viable sites and greater flow speeds near the free surface. However, the close proximity of the free surface provides concerns regarding power delivery and survivability due to the presence of waves. This has led to the development of a coupled and fully-nonlinear numerical model within the open-source CFD environment, OpenFOAM, capable of evaluating the performance and behaviour of full floating tidal systems [1,2,3]. The model solves the incompressible Reynolds-Averaged Navier Stokes equations for a two-phase fluid, tracks the motion of the system in six degrees of freedom, and uses expression-based boundary conditions for wave generation [4], along with a two-way coupled, actuator method to represent the turbine [1]. The model has previously been shown to agree with industry standard codes in relatively benign conditions, but has demonstrated additional complexities are present in more realistic conditions and these are not captured by simpler approaches.

This paper presents ongoing numerical and experimental work aimed at providing a detailed assessment of the Modular Tide Generator's (MTG) floating tidal platform concept prior to deployment of a full-scale prototype. The MTG prototype consists of a catamaran style hull, catenary mooring system and a submerged horizontal axis tidal turbine. Numerical predictions are compared with a series of 1/12 scale physical experiments, conducted in the COAST laboratory's Ocean Basin at the University of Plymouth. The experimental turbine is represented using an aluminium porous disc, designed based on preliminary experiments conducted in the COAST laboratory. The behaviour of the full system has been explored in a range of wave, current, and wave-current conditions, both with and without the turbine. In each case, the device has been assessed for a number of properties, including the motion of the barge, tension in each of the mooring lines as well as thrust on the turbine.

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Abstracts: Session 7

Tidal Rotor Performance Assessment in Three Test Facilities

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A tidal rotor test program was undertaken in the frame of a joint project between Cranfield University and Designcraft Ltd under the Innovate UK Energy Catalyst Round 4. The tests took place at 1:30 scale in Cranfield University ("small" towing tank), 1:18 scale in QinetiQ ("large" towing tank) and IFREMER (circulating tank). Due to the number of configurations (rotors, rotor yaw and blade pitch angles, surface finish), the use of a small, low cost, in-house test facilty was required initially to pre-select the rotor designs having a sustained effiency across the range of yaw and pitch angles. The effect of tank size was later assessed by conducting similar tests in a much wider and longer towing tank. A difference in Cp and Ct was clearly measured between the small and the large towing tank. A long towing tank presents an attractive set-up to run a large number of tests quickly, but most do not yet have the capability of generating a calibrated level of turbulence intensity. An important aspect of the test program, and of a tidal rotor design, was and remains to assess the influence of turbulence on the performance (Cp-Ct) of the proposed rotors. A circulating tank was then used without flow straighteners to reach 16% turbulence intensity. The results show that turbulence can affect the rotor performance differently depending not only on the blade shape but also on the pitch angle. Such comparative exercise between rotors and test facilities has lead to some worthwile findings regarding the flow velocity required to reach convergence of the Cp and Ct parameters. Finally, the difference in Cp values between rotors was found to be similar between a small towing tank and a circulating tank at 16 % turbulence intensity, reinforcing the benefits of using extensively the smaller facility initially.

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Could Large Tidal Turbine Arrays Affect Nearby Sandbanks?

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Fast tidal currents of interest for power generation often occur close to islands or headlands [1], where flow separation can occur and cause large areas of recirculation, extending over many kilometres. This is the case for two sites of interest in the English Channel, at Alderney (an island in the Normandy-Brittany Gulf)and Portland (a headland on the south coast of the UK). In both locations, large submerged sandbanks exist within a few hundred meters of flows that exceed 3 m/s at spring tides – flows that could easily remove the sandbanks, if diverted onto them. The sandbanks are revealed by repeated high-resolution swath bathymetry as highly dynamic places where large sand waves can propagate tens of meters in a day. Numerical modelling of these sandbanks in their natural state is a challenge due to the large range of temporal and spatial scales involved along with many uncertain parameters; extending such models to include large arrays of tidal turbines is even more challenging.

Nevertheless, it is important to be able to assess the likely impacts on sandbanks of potential tidal power developments nearby. Sandbanks are of ecological significance and their precise location is important for safe navigation. This presentation will characterize the sandbanks in terms of their dynamics; describe numerical modelling approaches including the importance of incorporating a non-erodible bed; and present results indicating the range of possible impacts of very large tidal turbine arrays on the hydrodynamics around Alderney South Banks.

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Abstracts: Session 7

The Development and Testing of a Lab-Scale Tidal Stream Turbine for the Study of Dynamic Device Loading

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The presentation outlines the development and testing of a 0.9m diameter lab-scale tidal stream turbine. The turbine was developed based on design experience acquired at Cardiff University during the development and testing of a number of legacy lab-scale TSTs [1] [2]. The development of the aforementioned TST was undertaken specifically to test under dynamic labscale conditions including both wave, turbulence and, ultimately, dynamic loadings imparted due to the situation of the TSTs in an array. A brief overview of the turbine rotor and blade design is given. The blade profile used for the 0.9m TST is that of an adapted Wortmann FX 63-137. The twist of the blade over the blade length and chord length at the blade root were both reduced to improve efficiencies and reduce thrust loading relative to previous scale models developed at Cardiff University [3]. Secondly, an overview of the turbine drive train and general design is provided. The TST is of direct-drive design with an integrated permanent magnet synchronous machine (PMSM) for turbine control. The details of the drive train design are supplemented with discussion of solutions to dynamic operational equations to check the inertial matching, resonances and antiresonances of the system. This section is followed by discussion of the drive system and power conditioning utilised to allow for effective turbine control via the integrated PMSM. Next, an overview of the instrumentation design process is given. The TST boasts rotor torque and thrust load measurements, blade root bending moments measurements on each of the three turbine blades, position and PMSM operational measurements. Details of the integration of the instrumentation systems via a Native Instruments CompactRIO are also given. Data presented shows the initial characterisation of the TST. The paper closes with appraisal of the design and details of future work.

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