Curriculum Vitae

Professor Richard H.J. Willden

Professor of Engineering Science

Employment history

2018-	Professor of Engineering Science EPSRC Established Career Fellow	Department of Engineering Science, University of Oxford
2012-	Tutorial Fellow	St Edmund Hall, University of Oxford
2007-2012	RCUK Fellow & University Lecturer Stipendiary lecturer	Department of Engineering Science, University of Oxford Christ Church, University of Oxford
2003-2007	RAEng / EPSRC Research fellow	Department of Aeronautics, Imperial College London
2002-2003	Research Assistant	Department of Engineering, University of Cambridge
1998-2002	Research Assistant	Department of Aeronautics, Imperial College London

Academic qualifications

Ph.D.	2003	Numerical Prediction of the Vortex-Induced Vibrations of Marine Riser Pipes	Imperial College London
M.Eng.	1998	Aeronautical Engineering (first class honours)	Imperial College London

Track record

Richard Willden holds an EPSRC Established Career Fellowship in tidal stream energy (2018-22) and is Professor of Engineering Science, having previously held an RCUK Fellowship in Marine Renewable Energy at Oxford (2007-12) and an RAEng/EPSRC Research Fellowship at Imperial College London (2003-07). In 2018 he became Co-Director of the UK's EPSRC funded Offshore Renewable Energy Supergen hub in which he is taking a leadership role in UK renewable energy research and delivery. Willden is also a Co-Investigator in the new EPSRC Centre for Doctoral Training in Wind and Marine Energy Systems and Structures (Strathclyde, Edinburgh and Oxford), in which he will be leading teaching and research in rotor fluid mechanics for wind and tidal stream energy.

Willden leads the fluid mechanics research in renewable power generation at Oxford and currently leads a group of ten doctoral students and two research assistants with a further research assistant in process of appointment. His principal areas of research are in low speed fluid mechanics and include: renewable energy - wind and tidal stream energy extraction; devices, arrays and their optimization, bluff body flows and flow-induced vibrations, and Computational Fluid Dynamics. In addition to current students and research assistants he has had twelve successful PhD completions all in under four years, and has supervised five research assistants in these areas.

He has authored and co-authored around one hundred journal, referred conference papers and invited talks in these fields as well as reports for industry. His group's principal contributions in the field of renewable energy include the development of multi-scale analytic energy extraction models, the development of the limit for energy extraction by turbine arrays partially spanning wide channels (Nishino & Willden 2012), the assessment and understanding of the fluid mechanical performance of prototype tidal turbine devices in realistic offshore flow conditions, the development and use of constructive interference design methods, as well as the development of reduced order simulation methods and directionally dependent turbine rotor tip corrections.

In addition to his Co-Directorship of the EPSRC Supergen ORE hub, and being a Co-Investigator in the EPSRC CDT for Wind and Marine Energy Systems and Structures, he has been the Oxford PI on three major marine energy research projects; the Energy Technologies Institute funded PerAWaT project, the Oxford Martin School project on "Globalising Tidal Power Generation", and his EPSRC Fellowship on "Tidal Stream Energy – Designing for Performance".

The focus of Willden's Fellowship is on the development and demonstration of disruptive technologies for tidal stream energy. Specifically, Willden has pioneered the use of constructive interference design methods to design tidal rotors for operation in arrays that enable them to operate at significantly higher efficiencies, and inferred reduced cost, relative to existing commercial systems. Willden's tidal stream research is concerned with using these methods to exploit the higher limit of energy extraction that is available in tidal flows (79.8% of kinetic energy flux, c.f. 59.3% for wind) that was derived by Nishino and Willden in 2012 for turbine arrays partially spanning very wide tidal channels.

In 2019 Willden's group completed two successful tidal turbine test campaigns of two 1.2m diameter rotors that were specifically designed for side-by-side operation using the constructive interference design methods developed by his group. The first of these tests, partly funded by a Supergen Marine Flex Fund project, was at

FloWave in Edinburgh and demonstrated a 20% performance uplift through designing for and then operating in a side-by-side configuration. The second of these tests, with facilities access supported through Marinet2, towed the same two turbines through the long tow channel at SSPA in Gothenburg. By using a movable attachment mechanism, turbine performance was tested as a function of intra-turbine spacing, including towing close to the tank wall to use the image system to test a four turbine array. These are novel experiments, at significant post-transitional scale, that have delivered new physics, validated key aspects of the underlying partial fence theory, and demonstrated the highest performance tidal turbines that have yet been tested at either laboratory or commercial scale. This is a disruptive technology that has been experimentally demonstrated to deliver very high performance with ensuing reductions in LCOE.

As well as the major projects identified above he has led EPSRC grants to demonstrate tidal fence technologies (Supergen Phase IV), to deliver a feasibility study on the design of floating tidal turbine fences with Harbin Engineering University, was Co-I on the Supergen Marine Challenge Project SMARTY concerning extreme loading and operational limits for marine energy converters, and is Co-I on the EPSRC project on Extreme wind and wave loads on the next generation of offshore wind turbines. He has conducted collaborative industry funded projects with Uniper, EdF, and E.ON in both tidal and wind energy. Specifically in wind energy he is working with energy utility EOn to develop new models for whole wind farm yield analysis that properly incorporate, hitherto unaccounted for, turbine-wake interactional effects. Between these and some smaller projects he has managed a grant portfolio of around £5M and contributed as Co-I to a further £17M of projects.

He has major international collaborations with Harbin Engineering University with whom he has a major Chinese grant from NSFC to develop tidal energy conversion technologies, with Shanghai Jiao Tong through EPSRC/NSFC support for offshore wind turbine research, and with University of São Paulo on tidal and wind technologies supported by an Oxford/FAPESP grant.

He is a member of the EPSRC College, was a member of the BSI Tidal resource committee PEL/114-11, and from 2011-13 was technical adviser on Marine Energy to the Energy Technologies Institute. He has provided hydrodynamic technical advice to major tidal energy device developers and to the UK Crown Estate. He has served as an editorial board member for an international journal as well as on several scientific committees for international conferences. In 2012 he instigated, and is chairman of, the now annual "Oxford Tidal Energy" workshop series, which has rapidly become an enthusiastically supported high-level technical meeting that attracts a sizeable audience (c. 90 attendees) with a significant international contingent from the USA to China.

Current Awards & funding

2018-22 **Willden, R.H.J.** EPSRC Established Career Fellowship: Tidal Stream Energy – Designing for Performance. EPSRC EP/R007322/1 (£1.024M)

2018-22 Greaves, D., Brennan, F., Byrne, B., Gilbert, J., Jeffrey, H., Scott, B., Stallard, T., Thies, P., White, D., **Willden, R.H.J.** & Zhao, X. Supergen ORE hub 2018. EPSRC EP/S000747/1 (c. £498k Oxford, £9.1M total)

2019-27 Leithead, B., Byrne, B.W., Brennan, F.P., Venugopal, V., McDonald, A., Viola, I, **Willden, R.H.J.**, Carroll, J., Martin, C.M., Kolios, A., O'Bradaigh, C. EPSRC Centre for Doctoral Training in Wind and Marine Energy Systems and Structures. EPSRC EP/S023801/1 (£6.424M)

2019-23 **Willden, R.H.J.** & Vogel, C.R. Wind farm wake modelling, CASE Award: EPSRC & EOn (£104k)

2019-23 **Willden, R.H.J.** & Vogel, C.R. Wind turbine wake analysis and modelling, EOn studentship support (£28k)

2018-22 Jing, F., Sheng, Q., Zhang, L. & **Willden, R.H.J.** Theoretical and Experimental Research on Flow Field Characteristics and Coupling Dynamics of Tidal Energy Converter. NSFC (China) (3M RMB)

2017-20 Adcock, T., Borthwick, A., **Willden, R.H.J.**, van den Bremer, T., McAdam, R. Extreme wind and wave loads on the next generation of offshore wind turbines, EPSRC EP/R007632/1. (£400k Oxford, £798k tot)

Key Recent Publications

McNaughton, J., Cao, B., Vogel, C.R. & Willden, R.H.J. (2019). Model scale testing of multi-rotor arrays designed to exploit constructive interference effects. In Proc. *13th European Wave and Tidal Energy Conference*.

Wimshurst, A. & Willden, R.H.J. (2018). Computational Observations of the Tip Loss Mechanism Experienced by Horizontal Axis Rotors. *Wind Energy* **21**, pages 544-557.

Vogel, C.R., Houlsby, G.T. & Willden, R.H.J. (2016). Effect of free surface deformation on the extractable power of a finite width turbine array. *Renewable Energy* **88**, pages 317-324.

Schluntz, J. & Willden, R.H.J. (2015). The effect of blockage on tidal turbine rotor design and performance. *Renewable Energy* **81**, pages 432-441.

Nishino, T. & Willden, R.H.J. (2012). The efficiency of an array of tidal turbines partially blocking a wide channel. *Journal of Fluid Mechanics* **708**, pages 596-606.